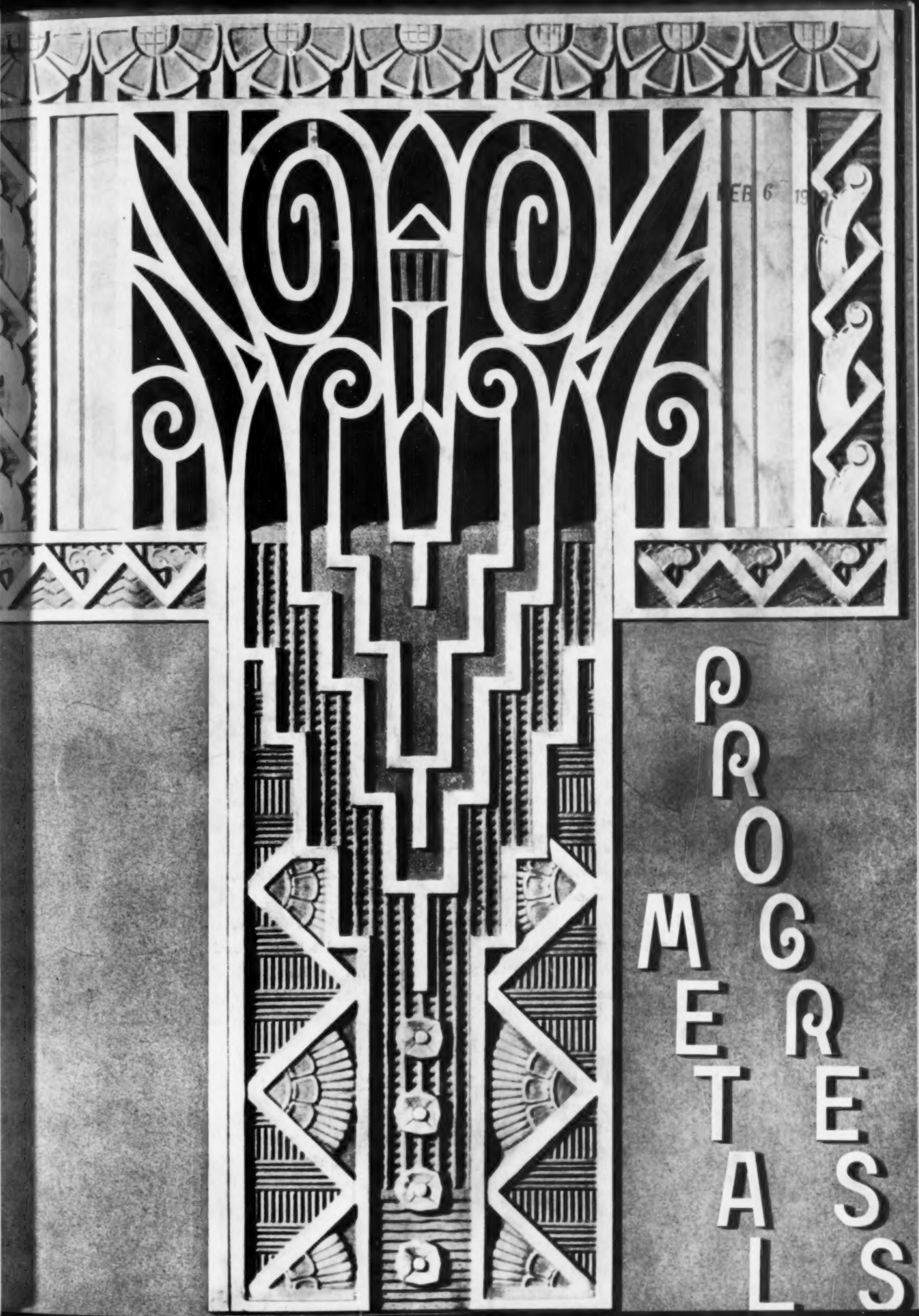
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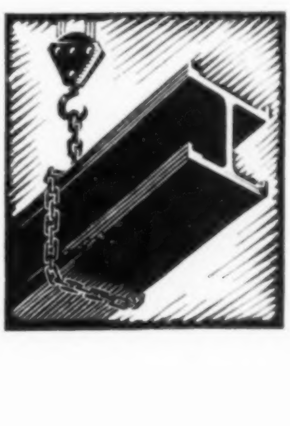

Ernest E. Thum, Editor

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Sampling an Electric Heat, as Photographed by Bourke-White at Republic Steel Corp.

MANUFACTURE OF STAINLESS IRON

from ferrochromium, from scrap, or from ore

By A. L. Feild
President, Alloy Research Corp.
Consulting Metallurgist
Rustless Iron Corp. of America

HIGH chromium steels of the corrosion and heat resistant types represent a specialized field of steel making where experience, sound knowledge of metallurgical principles, and an important degree of skill are each of considerably more than average importance. This is due to the peculiar chemical properties of the element chromium at steel-making temperatures; for example, *molten* chromium is oxidized in preference to iron from molten alloys, and has a powerful affinity for carbon.

Before the advent of the stainless steels, the melting of chromium alloy steels was chiefly concerned with the introduction of comparatively small percentages into the metal bath, say from 0.50 to 1.75%. No unusual precautions to avoid carbon contamination were required nor was the matter of oxidation of chromium in such small amounts any more serious than that for corresponding small percentages of manganese (with which all steel makers had long been familiar).

An entirely different set of problems appears when a 16% Cr, 0.10% C steel is to be made. It was early learned that carbon could not be removed from such a bath by any of the generally known procedures for plain or alloy steels. One of the commonest experiences in the early days was to observe a high chromium bath which, under oxidizing conditions in the electric furnace supposedly proper for reducing the carbon, would increase in carbon content and simultaneously lose chromium rapidly to the slag! Under these circumstances it is not surprising that the first of these special alloy steels were made commercially from low carbon raw materials under conditions which prevented loss of chromium by oxidation and absorption of carbon. This represents, in fact, the principles now employed.

Use of Low Carbon Ferro

All ordinary low carbon stainless steels and irons (chromium 12% or more, carbon 0.10% maximum) are manufactured in America in a basic electric arc furnace of the Heroult type, illustrated on page 15. (The one exception to this statement is stainless scrap remelted in electric induction furnaces.) The 6-ton furnace

is a favorite size; it is customary with good practice to produce around 18,000 lb. of ingots per heat from it.

The initial charge of raw material consists of ordinary low phosphorus steel scrap. Roll scale or iron ore is then added (200 to 500 lb. into a 6-ton furnace) and the mixture is melted by the electric arc. During this period the carbon in the melt is lowered to 0.04% or less, and the slag is removed. The metal bath should be cleaned as free from this oxidizing slag as possible, because from this point on every effort will be made to maintain non-oxidizing conditions. A finishing slag made of lime and fluorspar is then placed on the bath. So far practice is similar to the manufacture of any high grade alloy steel.

Pulverized ferrosilicon (and more lime when necessary) is added to the slag from time to time during the remainder of the heat to maintain a slag known as the disintegrating calcium silicate type; ferrosilicon keeps it as free from iron oxide and chromium oxide as possible by virtue of the fact that silicon will reduce those oxides in the slag, returning the metals to the bath.

When the finishing slag has been worked into shape, the necessary quantity of low carbon ferrochrome is added. It is customary to make it in two or three lots, a certain period elapsing between additions, to heat and melt the ferrochrome and to superheat the metal preparatory to a subsequent addition.

Extreme precautions must be taken to avoid any actual contact of the electrodes with the metal bath. A sharp watch should be kept for pieces of carbon or graphite in the slag, and when discovered they should be removed as quickly as possible; even so, occasional heats may run high in carbon from this cause or from improper electrode control.

When the ferrochrome has become incorporated in the bath and thoroughly mixed by stirring with a rod, metal tests are taken at intervals of 10 to 30 min. and are analyzed for carbon, chromium, manganese, silicon, and any other alloying elements such as nickel which may be present. Correcting additions of alloying elements are then made; the bath is brought to the proper temperature, final deoxidizing additions are made in the furnace, and the heat is poured out of the furnace into a ladle and thence into molds.

Variations in this conventional method from plant to plant include differences in the exact method of introducing the ferrochrome and in deoxidizing procedure.

Since the low carbon metal in the bath prior to the addition of ferrochrome has an unusually high melting point, and since an appreciable degree of superheat is necessary before making an addition of cold ferrochrome, one of the problems of manufacture is to avoid excessive wear on the refractories.

All high chromium steels are relatively thick and sluggish and an accurate estimate of tapping temperature can be made only by an experienced operator. The appearance and behavior of this molten metal also depends to a considerable extent on the percentage of silicon and on the presence of supplementary alloying elements. The presence of chromium, even in large percentages, does not appreciably lower the freezing point of iron.

The time required to make such a heat, for example in a 6-ton Heroult furnace, depends not only upon skill of the operator and the particular procedure employed in introducing ferrochrome into the bath but also upon the capacity of available electrical equipment. It will probably average around 5 hr. Average power consumption will be in the neighborhood of 650 kw-hr. per ton of ingots.

A somewhat detailed account of the conventional method of melting the low carbon variety of high chromium steels has been presented, because this grade is commercially the most important and the melting practice represents the extreme degree of specialization. The presence of nickel in these high chromium steels introduces no additional complications, even though its percentage varies from 8 to 35%, except that to obtain satisfactory hot working properties it is customary to make an addition of 0.1% magnesium shortly before tapping. Stick magnesium may be tied to a rod and quickly thrust into the bath. Since magnesium is a violently reactive metal the operator must be protected against slag or metal which may be ejected through the door. It has been suggested that the function of magnesium in these high nickel alloys is related to sulphur.

The high chromium steels occupy a unique position in the field of ferrous metallurgy. They are relatively expensive and at the same time are produced in a very considerable tonnage to meet demands which are constantly widening. While there are no statistics available, it is certain that the potential market has been exploited only to a small extent. *Price* in most instances is the determining factor as to whether or not stainless will be used for a given part.

Six-Ton Furnace of Heroult Type, Pouring a Finished Heat of Steel at Bethlehem Steel Co.

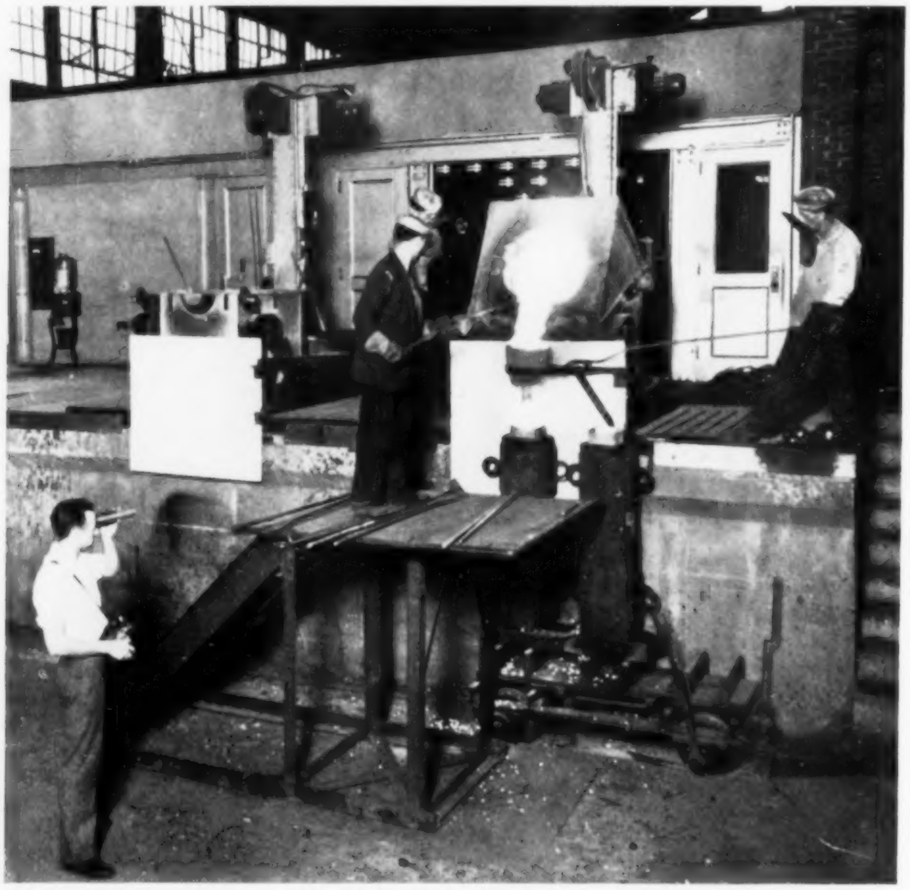
What chance is there that the price of the stainless alloys may be reduced?

In the conventional method of melting low carbon stainless steel and iron in the electric furnace, technique has been perfected to the point where there is little opportunity for lowering ingot costs except from a revision in the price of low carbon ferrochrome. (It should be mentioned here that low carbon ferrochrome is manufactured from chrome ore by a complex and highly specialized process which involves, first, the production of a low carbon chromium-silicon-iron alloy—containing up to 50% silicon — by the carbon reduction of a mixture of chromite and quartzite in a submerged electrode furnace, and next the treatment of this ternary alloy in a separate furnacing operation with chrome ore, thereby eliminating the silicon and enriching the alloy in chromium. High carbon ferrochrome — containing 4 to 6% carbon — is produced in a single step by reducing chrome ore with carbon.)

The question of how cheaply low carbon ferrochrome can eventually be made and sold at a fair profit is one which can be answered only by the ferro-alloy manufacturer. The steel trade, however, has to date no reasonable right to expect to purchase it at any price closely approaching the level for high carbon ferrochrome. In spite of the fact that the cost of low carbon ferrochrome is the largest factor in total ingot cost, manufacture of stainless alloys from this ferro-alloy offers attractive possibilities for the product in a number of markets.

Reclamation of Scrap

To the uninitiated the spread between ingot cost and the selling price of the sheet, bar, or tube appears excessive. Contributory causes of this differential over carbon steels are: (1) The cost of grinding the entire surface at some stage of processing, usually the slab, billet, or sheet-bar; (2) the extra time and fuel required in all heating operations; (3) a reduced capacity of rolling mills; (4) the rigid inspection required to turn out a uniform high-quality



High Frequency Induction Furnace Pouring Stainless Steel at Carpenter Steel Co. The observer on the lower level measures heat with an optical pyrometer

product; (5) the relatively small available tonnage; and (6) the abnormal effect of scrap on the cost of the finished product. The first five factors may only be mentioned, but the last is intimately related to the melting operation.

Stainless iron scrap may be purchased today for 1 to 1½¢ per lb. This is so much less than the intrinsic value of useful metal that when a 20% discard is taken from the top and bottom of an ingot, the cost of the remaining 80% jumps approximately one-fifth, even after crediting the value of the scrap. The situation becomes rapidly and increasingly worse as other unavoidable losses are incurred and as the material in process becomes a more highly manufactured article. It is because of this wide spread between the value of stainless iron ingots and scrap of the same analysis that the net cost per pound of metal in hot rolled sheets, for example, is about twice that of the original ingot (without including any of the direct or indirect costs of processing from ingot to sheet, or of final preparation of the surface).

If it were possible to convert stainless scrap into ingots of the same analysis as cheaply as one can plain carbon or ordinary alloy steels, the cost of the average production would be materially reduced. Actually, the remelting of scrap is an art in itself, complicated by those same metallurgical peculiarities of chromium which have already been discussed, not to mention certain other features peculiar to scrap itself. Attempts to remelt in an electric arc furnace by ordinary methods lead, for example, to a prohibitively great increase in carbon content, unless, of course, conversion to an analysis in the medium or high carbon range is the object.

One method of remelting low carbon stainless scrap uses the electric induction furnace, of which there are two common types. One of these — the low frequency furnace of the Röchling-Rodenhauser type — is built like a low voltage transformer, the bath of molten metal forming the secondary circuit. Of necessity melting is conducted in a ring-shaped crucible, thermally insulated from the primary circuit. Such a furnace of nominal 6-ton capacity is in use at Canton, Ohio; another has seen considerable service at Brackenridge, Pa. The Canton furnace operates with 800 kw. of power, melts in an atmosphere of natural gas, and taps about 9,000 lb. of metal every 3 hr.

Remelting scrap in a high frequency induction furnace of the well-known Ajax-Northrup type is being practiced in several plants; the largest furnace has 4 tons capacity (at South Chicago). The advantages claimed are greater ease of manipulation and maintenance.

Since induction melting uses no electrodes, it is readily possible to remelt low carbon, high chromium steel scrap without increase in carbon content. To this extent at least, the method is metallurgically ideal. Oxidation of chromium can be controlled and reduced to an inconsequential amount. Electromagnetic stirring caused by the alternating currents induced within the molten metal is efficient. Commercial manufacture by induction melting is a comparatively recent delevopment, and available information is too incomplete for me to make any estimates of the possible effect on the economics of production.

Production From Chrome Ore

The relatively high cost of low carbon ferrochrome has acted as a spur to devise ways and means of producing low carbon, high chromium steels from other materials.

The first effort along this line in the United States which attained the dignity of continuous commercial production was made at Baltimore in 1926 by Ronald Wild of Sheffield, England, and during the period 1926 to 1931 he placed the direct production of stainless iron ingots from chrome ore, using ferrosilicon as a reducing agent, on a practicable working basis.

Melting at Baltimore, as developed and practiced by Wild, involved charging low phosphorus steel scrap, limestone, and iron ore into a standard 6-ton Heroult furnace after the fashion of ordinary practice, lowering the carbon to the necessary low percentage by oxidation and removing the oxidizing slag. Thereafter successive additions of chrome ore and ferrosilicon were charged, the slag resulting from the reduction process being removed from time to time. An excess of chrome ore to ferrosilicon was employed to obtain a low carbon, low silicon product.

Metallurgically, this resembles conventional melting practice only in the type of equipment employed, in the method of preparing the initial low carbon metal bath, and in pouring practice. With the exception of the final finishing period, the slag contains of necessity appreciable percentages of the oxides of chromium and iron. Reduction proceeds relatively slowly, and the time for a heat is considerably longer. This ore process is operative when the saving due to cheap raw material, ore, instead of low carbon ferrochrome, more than offsets the cost of the ferrosilicon reducing agent and the longer time of heat.

In addition to ore as a cheap source of chromium, consideration has been given to high carbon ferrochrome of the ordinary 4 to 6% carbon grade. During 1926 and 1927 A. L. Feild conducted experimental work at Canton, Ohio, in a 2-ton Heroult furnace on the manufacture of stainless iron from this substance. Work was then discontinued but commercial manufacture was begun in 1929 at Lockport, N. Y., where a 6-ton Heroult furnace was employed.

Obviously, any process involving the use of high carbon ferrochrome in the production of low carbon, high chromium steels is based on a decarbonizing procedure. Carbon is taken out of a bath by oxidation. Experience has shown that such a procedure is not economically attractive or is commercially inoperative or both unless means are provided for recovering that part of the chromium which is oxidized concurrently with carbon. Such means have been a distinctive feature of the above-mentioned melting practices, ferrosilicon being employed as a reducing agent.

Future Expectancies

It is within the bounds of reasonable expectation that economic pressure and competition between the several melting processes will soon bring about some balance between metallurgical inventiveness and skill, on the one hand, and those fundamental items of basic cost which characterize all metallurgical melting processes. Even then the high chromium steels will always remain considerably more costly than ordinary steel. But if it is possible to produce steel ingots containing 0.10% carbon and 18% chromium, for instance, at a manufacturing cost of from 2½ to 4¢ per lb., there is no reason why the subsequent processes of heating and rolling to the finished sheet, strip, or bar should not be conducted on a scale sufficiently large and efficient to justify a selling price which would open up markets and applications not dreamed of except by believers in the philosophers' stone.

WORKABILITY OF HIGH BRASS SHEET

influenced by hardness, ductility and grain size

By M. H. Medwedeff
Metallurgical Engineer
A C Spark Plug Co.
Flint, Mich.

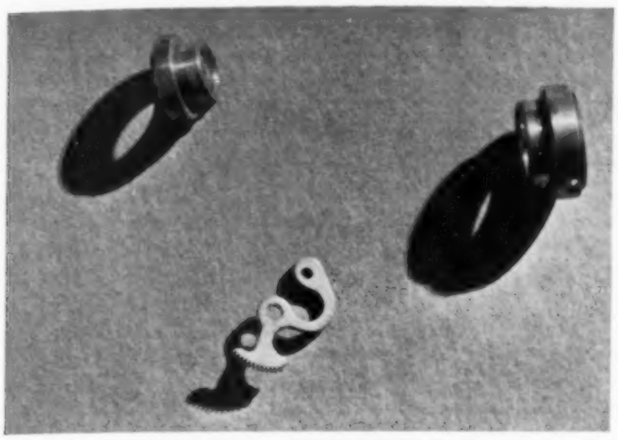
BRASSES, generally speaking, are alloys in which copper and zinc are the principal metals. Ductility, workability, and strength of these alloys are influenced primarily by their composition and the amount of cold work which has been put on them since the last anneal. In the most important commercial brasses the percentage of zinc is the ruling chemical consideration; in the less important types additions of lead, tin, manganese (alone or with iron and aluminum) must be reckoned with. The general term "brass" also includes the so-called german silvers or nickel silvers, which are alloys of copper, nickel, and zinc — in other words, brasses in which the zinc is partly replaced by nickel.

By far the most important of the copper-zinc alloys are those known to metallographers as alpha brasses. This was the type of brass known to the ancients, perhaps for the simple reason that the alpha brasses are the most easily workable. In other words, there are no fundamental difficulties in working an alpha brass and our ancestors learned by trial and error what "don't's" to avoid. One cannot but marvel at the results they obtained.

It is well known that alpha brasses are solid solution alloys, that is, any amount of solid zinc up to about 39% is dissolved in the solid copper without forming a definite chemical compound. The zinc atoms merely replace atoms of copper in the original lattice space of copper. The original face-centered cubic lattice of pure copper remains the same, except for a slight expansion in size, and hence the structure under the microscope is very much the same as that of pure copper. Polyhedral crystals of a single constituent are formed which are easily twinned by strain and subsequent release of strain, as by annealing. It is due to this simple structure and crystalline lattice that these brasses are so very ductile.

Among the alloys of great industrial importance belonging to this group, may be mentioned cartridge brass, which is made to the following chemical specifications: Copper 66.5 to 69.5%, lead 0.07% maximum, iron 0.05% maximum, and zinc 32.5 to 30.5%. This is the highest type of brass, as will be noted from the very low percentage of impurities.

Another analysis of commercial brass sheet is most commonly used in the automotive industry. It is known as high brass to the producers, and commonly referred to by consumers as S.A.E. No. 70. According to the Society of Automotive Engineers' standards, the composition of



Leaded High Brass Insures Good Machinability
Two small valve seats for A C fuel pump have elongation of 18 to 25% for ball assembly; Oil gage sector is punched from clock brass (elongation 8 to 12%) and teeth machined

this brass is copper 64.5 to 67.5%, lead 0.30% maximum, iron 0.05% maximum, other impurities 0.10% maximum, and zinc 35.5 to 32.5%. Most of the remainder of this article will concern itself with the workability of this material in sheet form.

It was not so very long ago that, like the tool steel manufacturer, the brass mill sold its product entirely under some high-sounding trade name. This condition actually persists in certain places where old-timers still manage to combine a euphonious name with modern terminology, insisting that in this lies the magic of good quality.

It was then the common practice for the buyer to depend entirely upon the expert advice of the mill representative as to the kind (brand) of brass he needed. This relationship undoubtedly worked to the mutual advantage of both parties when manufacturing conditions were simple, and presses and dies less complicated. But with the advent of large quantity production of intricate parts, this relationship became entirely inadequate and the modern brass user began to realize that he had to solve his own problems and develop his own organization to study the best types of materials suitable to his needs, just as he had to learn the best type and size of machine or press to make his parts and the best design of tools or dies with which to manufacture in the most economical manner. Hence it is that consumers are studying the properties of metal even more intently than the producers, and this condition has resulted in the purchase under specification as an organization policy by the large companies. Only in isolated cases is the mill allowed to send material identified by a brand name.

This brings us to the main question: What compositions and what properties are best suited to generic types of products such as drawn, or machined parts, and what are the criterions by which these can best be arrived at?

Severely Drawn Parts

For parts which are designed to be drawn, the character of material is dependent upon how much drawing the design calls for and also in some measure upon the cost of the brass and what initial costs the product can stand. Where the drawing operation is of extreme depth, such as a cartridge case and other deeply cupped objects, the highest ductility is desired. Highest ductility is possible with cartridge brass. This metal, however, costs more than the high brass of the S.A.E. No. 70 type, so that a decision must be made between using the higher priced metal or the cheaper metal even though the latter may require an annealing operation during the processing. For parts where the drawing operation is not so severe, somewhat harder metal with a lower ductility can be accepted. Experience in each particular shop dictates the degree of ductility which each design and die set-up requires.

This brings us to the quantitative interpretation of ductility in relation to design and other factors which call for a combination of strength and ductility. This also has a considerable influence upon the finishing properties.

Manufacturers who are called upon to process a large variety of intricate parts are compelled to lay particular stress on correct specifications for ductility and hardness. It must be said to the credit of the brass manufacturers that they have spent a great deal of time and effort to work out methods of control through the various steps in processing sheet

brass, so as to enable them to furnish sheet and strip to any degree of ductility demanded by the requirements of the user.

The best method of controlling ductility (more precisely "draw-ability"), and indirectly hardness, is through the tensile strength and elongation, as determined on a standard type of tensile test strip. These tests give the only reliable index as to what one can expect from a given lot of material. But this very desirable and reliable test is time-consuming and somewhat costly, especially in the preparation of test pieces, so that for general routine purposes the brass mill and the user are compelled to resort to a more ready method of inspection.

The testing equipment generally used is the Rockwell hardness testing machine and the Erichsen or Olsen ductility testers. The Rockwell is the more reliable of these tests and it is therefore generally used for specification purposes and also for inspection, in control work. However, in cases where the requirements for drawability are exacting, the elongation should always be specified.

It is generally understood that Rockwell hardness tests are meaningless on stock under 0.020 in. The purchaser and the mill must also have an understanding as to the conditions of this test, that is, whether the $\frac{1}{8}$-in. or $\frac{1}{16}$-in. ball should be used, whether one or several thicknesses of stock are piled on the testing machine anvil, and whether the load is to be 100 or 60 kg. In my opinion, the best practice is to use one thickness of stock and make an allowance subject to mutual agreement for the anvil effect, particularly for the soft brasses below a certain thickness.

The table above gives the generally accepted Rockwell hardness values on brasses of different degrees of ductility or "tempers," tested with the $\frac{1}{16}$-in. ball, 100 kg., B scale.

Sometimes it is preferable to use a magnified scale of hardness. Then the 60-kg. load may be used by mutual consent. The table on the next page gives the generally accepted hardness values under this scale.

These tables represent average hardness values which have been arrived at through a period of time and can be accepted as truly representative for sheet brasses in general.

It was stated above that the Rockwell hardness tests are not reliable for sheets under 0.020 in. thickness. If a definite degree of ductility is of utmost importance, a specification for ductility expressed by elongation is then essential. The numerical value specified will depend on the nature of the product, details of the design, and character of the die. Elongation will therefore vary from 20% up to 45% for a severe draw. Experience must dictate.

It must, however, be realized that a specification for elongation is not sufficient by itself. We can conceive of two sheets of brass with approximately the same elongation and yet one will draw while the other will either break through, or at best give a very rough appearing surface at the regions of maximum draw. This is known as "orange peel," which it resembles.

This difference is due to the fact that the brass sheet which draws well has a relatively small grain, while the one which develops the orange peel effect has a coarse grain.

To guard against this condition and insure a quality product we must incorporate a provision for grain size in our specification. Proper grain size has another more direct economic advantage; tests made over a period of time indicate that fine-grained brass parts can be polished preparatory to plating with a saving in time of about 30%.

The photomicrographs will show very clearly the types of structure one may expect and get. A very great difference exists, and a brass with a structure shown in the first two micros will draw well, while the very coarse

ROCKWELL B HARDNESS OF SINGLE SHEETS OF HIGH

[1/16-In. Ball, 100 kg. Load]

Temper	Thickness of Single Sheet				
	0.015 in.	0.020 in.	0.025 in.	0.030 in.	0.050 in.
Dead soft		20	17	15	10
Soft annealed		10 to 32	12 to 30	4 to 29	0 to 25
Blue annealed		25 to 45	23 to 44	21 to 43	18 to 42
1/4 hard		30 to 52	33 to 55	36 to 57	40 to 62
1/2 hard		47 to 69	50 to 72	52 to 74	56 to 76
3/4 hard	62 to 75	65 to 79	67 to 81	68 to 82	71 to 84
Hard	74 to 82	76 to 84	78 to 86	79 to 86.5	81 to 87.5
Spring hard	78 to 86	82 to 88	83 to 89	84 to 89.5	85 to 89

ROCKWELL B HARDNESS OF SINGLE SHEETS OF HIGH BRASS
[1/16-In. Ball, 60 kg. Load]

Temper	Thickness of Single Sheet					
	0.010 in.	0.015 in.	0.020 in.	0.025 in.	0.030 in.	0.050 in. and Over
Dead soft		71	68	66	64	62
Soft annealed		66 to 78	63 to 75.5	60.5 to 73.5	58 to 72.5	56 to 71.5
Blue annealed		74 to 83.5	71.5 to 81.5	69.5 to 80	68.5 to 79.5	67.5 to 79.5
1/4 hard		74 to 88	76.5 to 89	77 to 90	78 to 91	80 to 92.5
1/2 hard		86 to 96	86.5 to 97	87 to 97.5	87.5 to 97.5	89 to 99
3/4 hard	93 to 100	96 to 101	96.5 to 101.5	97 to 102	97 to 102	98 to 103
Hard	99 to 102	100 to 103	100.5 to 103.5	101 to 104	101.5 to 104.5	102.5 to 105.5
Spring hard	101 to 104.5	102 to 105	102.5 to 105.5	103 to 106	103.5 to 107	104 to 108

grain either will not draw at all or will produce a very pronounced orange peel effect. Again, brass with the finest structure will polish with greater ease than brass with the medium grain size, while metal with the very coarse structure shown in the third micro will polish very poorly — that is to say, it will be very difficult to remove the orange peel roughening.

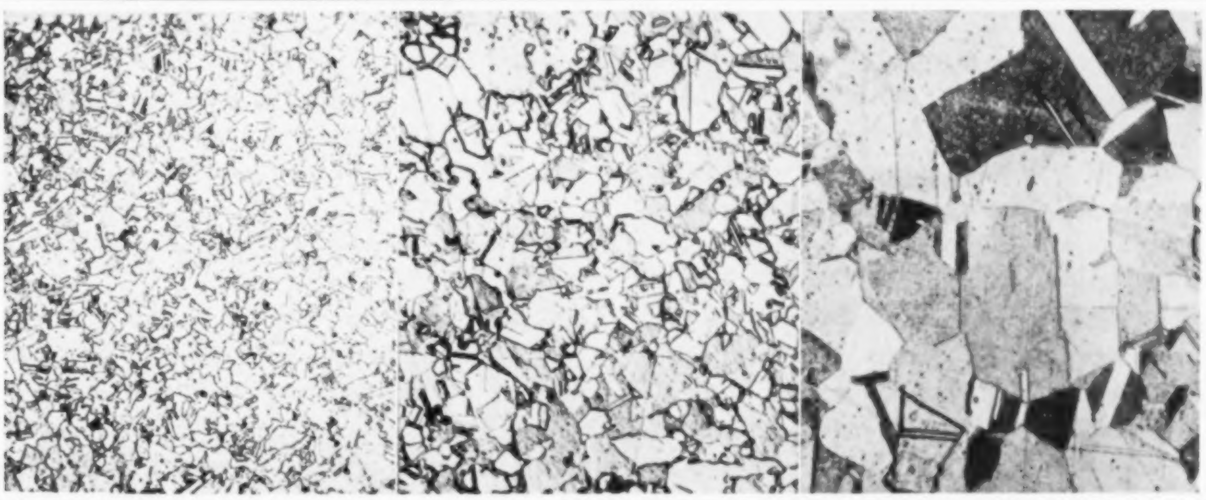
It must be stated that it is within the ability of the mills to produce brass sheets for deep drawing requirements which can combine fine grain size with very good ductility — as high as 40% to 50%. Grain size may be most conveniently measured, as noted by Dr. Jeffries, by drawing a random line across a photomicrograph, counting the number of boundaries it crosses (neglecting twin lines) and figuring the average size from the length of the line and the magnification of the photograph.

The *german silvers* mentioned at the outset are also solid solution alloys, and have properties very much the same as those described above. They are, therefore, good drawing materials. The structures of these brasses are very similar to the ones shown below, except that the german silvers are not as susceptible to large grain growth under manufacturing conditions. However, they harden more readily in working than the straight copper-zinc brasses.

Commercial compositions range from 52 to 63% copper, 30 to 26% zinc, and 6 to 22% nickel. Tensile strength depends on analysis and history, but it is a rough approximation to say that it is 10% greater than the tensile strength of the straight copper-zinc brasses reduced the same number of sheet gages since the last anneal. They are considerably more expensive than the straight brasses, but have a pleasing

Coarse Grain in Some Shipments of High Brass Causes Difficulties in Forming and Polishing

Very Fine Grain; 0.025 mm. *Medium Grain; 0.045 mm.* *Very Coarse Grain; 0.100 mm.*



Forms Stamped From High Brass of Various Tempers
A C spark plug terminal at top, elongation 30 to 35%; Ammeter bezel, elongation 30%; A C speedometer jewel frame, elongation 25% minimum, B-40 to B-55; Worm gear retainer of spring temper, B-50 to B-75

bright color and are used when greater resistance to tarnishing is required and to eliminate incidental plating operations on ordinary high brass.

Leaded brasses are of importance. Only those of low lead content are rolled into sheets, and are used where it is possible to sacrifice some ductility and gain some machinability. Some parts call for a combination of easy forming and free machinability, such as drilling or punching holes without leaving burrs. These brasses may have from 0.75 to 2% of lead.

It is important to bear in mind that leaded sheet brass should have a copper-zinc ratio the same as in high brass, that is 61%:37%, because if the ratio is permitted to approach 60:40 we may, under certain conditions, have a very undesirable structural condition in the brass where the alpha structure contains a second constituent known as beta. The practical importance of this lies in the fact that such brasses harden more rapidly in the forming operation, and this may result in the production of wasters.

Leaded sheet brasses are designated by the brass mills as "clock brasses." The range of composition of these brasses is 61 to 64% of copper, 0.75 to 2.0% lead, and the remainder zinc. Rockwell specifications already given for the various tempers or anneals of high brass apply to clock brass.

Another series of leaded brasses in the form of bars or rods is of considerable industrial importance. These are the so-called free-machining brasses. As pointed out by Crampton and Croft in the last issue of METAL PROGRESS, the degree of machinability increases with the lead content, but at the expense of a corresponding amount of ductility. It is therefore possible to specify the lead content to obtain a certain degree of free machinability combined with a certain degree of ductility or ability to stand permanent deformation without cracking. Thus, for parts which must stand some swaging or crimping, the lead content should not exceed 1.50%.

It is desirable at times that the specifications for these brasses should include provisions for elongation. This will generally vary from 12% to 25%, depending on the nature of the product. In some special cases it may be found necessary to specify elongation as high as 50%.

What was said before about the copper-zinc ratio applies with equal force to the free-machining brasses, or the so-called "high speed brasses." In the higher leaded brasses, the copper sometimes drops below 60%. Such a brass may have a good elongation in the direction of rolling and yet be brittle. This condition is generally associated with a microstructure containing both alpha and beta crystals. The only practical way to avoid this condition is to watch the copper-zinc ratio.

The importance of grain size in the free-machining brasses must also be recognized, because there are numerous applications for brass rod where grain size may play an important part either in manufacturing economy or in the usefulness of the part in service.

CLASSIFYING STEELS BY SPARKING

recommended practice for routine inspection

By W. G. Hildorf and C. H. McCollam
Metallurgist Chief Chemist
Timken Steel & Tube Co.

SPARK testing is a method for the classification of steels by the sparks thrown off when held against a high speed grinding wheel. The test is valuable as a safe-guard against the accidental mixing of steels of different analyses, or as a method for separating steels known to be mixed. It is fast, convenient, economical, and when applied with proper regard for its limitations, reliable and accurate.

Spark testing is not a substitute for chemical analysis, and is not intended for the identification of unknown samples. It is based on the idea that the character of sparks should be similar when streams are examined from a number of samples of the same material. Should one or more of the samples exhibit a spark stream of different character, the presence of a second material is indicated. Chemical analysis can then be used for positive identification, if such is desirable.

One of the advantages of the test is that it can be applied to steels in practically all stages of production — billet, bar stock in the racks, partly machined forgings, or finished parts. Since it is done directly on the pieces themselves, expensive sampling (with attendant possibilities of mix-ups in numbering and handling) is avoided.

Our theory of the action is as follows: When a piece of steel is held in contact with a moving emery wheel, small particles of the metal are torn loose. A high speed wheel tears metal so rapidly that the temperature of the particles is raised to incandescence. As they are hurled through the air the trajectory is quite easily seen, particularly against a dark background, due to the persistence of vision. This trajectory is called a carrier line. If the metal is either ingot iron or wrought iron, the result appears to be a small sheaf of single lines termed a spark picture. If a piece of carbon steel of about 0.15% carbon is held in contact with the wheel, the color of the line is lighter and the presence of a number of short single forks or primary bursts may be noted. See the first halftone.

These forks or bursts are doubtless due to the carbon in the steel. While

Prepared for the Recommended Practice Committee of the American Society for Steel Treating. Spark stream photographs were made at the Bureau of Standards and supplied by H. S. Rawdon, Chief of the Division of Metallurgy

Carrier Lines From Ingot Iron Are Smooth, but From a Low Carbon Steel Some of the Lines Are Forked

the fragment is incandescent and in contact with oxygen of the air, the solid carbon present is burned to gaseous carbon dioxide. Transition of solid to gas increases the volume enormously. Although the particle of hot steel is plastic, it offers some resistance to expansion and an internal gas pressure is formed which is only relieved by an explosion of the particle.

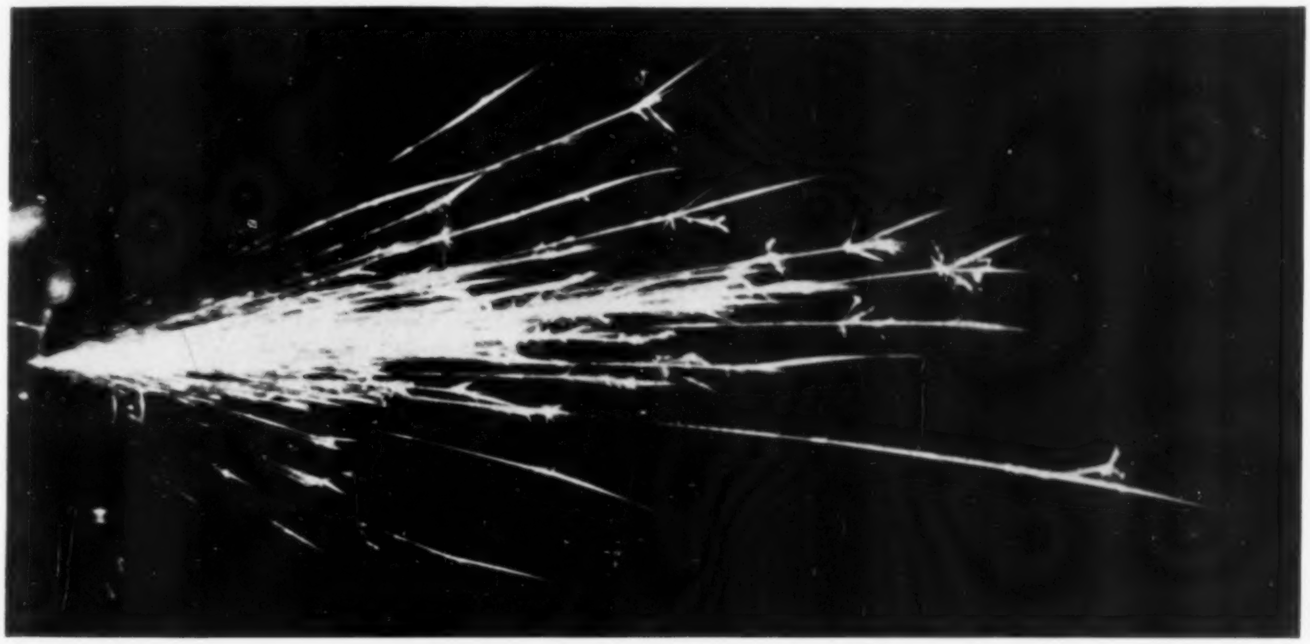
There are some observations to support this explanation of the phenomenon. For instance, the grinding dust, when cold, contains numerous hollow spheres with one side completely blown away. The relation of carbon content to the frequency of the bursts also marks carbon as the element responsible for the forking of the carrier line. A 0.15% carbon steel exhibits a slight forking effect, a 0.45% carbon steel a pronounced burst, and steel in the neighborhood of 1.00% carbon a minute explosion. Moreover, greater *intensity* of bursting is noticed

as the carbon content of the steel is increased.

Technique of the visual examination is quite important; when properly done, variations in the stream become more readily distinguishable to the trained observer.

When using a dark cabinet, to be described later, the operator should hold the pieces on the wheel in such a manner as to throw a horizontal spark stream about 12 in. long and at right angles to his line of vision. He must determine the right pressure to maintain a stream of about this length without reducing the speed for most efficient performance of the grinder. Wheel pressure is an important item, whether the piece be held against the wheel (as in cabinet work) or the wheel against the metal (as in mill or warehouse), because increasing the pressure will raise the temperature of the spark stream and bursts, and will, to the inexperienced eye, give the appearance of a higher carbon content. Experience will later dictate to the trained spark tester the length and volume of the spark stream required for the various steels that will be encountered.

Having determined the proper wheel pressure, it is suggested that the learner select two plain steels of widely different carbon content; a rivet and a cold chisel will do very well. First one, then the other, should be held against the wheel alternately, always being careful to strike the same portion of the wheel with each piece. With eyes focused on a point about one-third the distance from the tail end of the stream, watching only those sparks that cross the line of vision, he will form after a little while a mental image of the individual spark. After an operator can fix spark images in this manner he is prepared to examine the character of the spark picture.



Number and Intensity of Bursts in Carrier Lines Increase With Increasing Carbon in Plain Steels. Compare this spark picture of 0.45% C steel with that of a 1.0% C steel at the bottom of page 24

The entire sheaf of sparks may be divided into three equal sections, (*a*) the wheel sparks, which are the third of the stream nearest the wheel, (*b*) the center area, and (*c*) the tail sparks, which represent the third of the stream farthest from the wheel. The components to be observed are the carrier lines, the bursts and the characteristic sparks.

Carrier lines will vary in length, breadth, color, and number. They are the incandescent streaks which trace the trajectory of every glow-

ing particle, and are discussed more fully in connection with characteristic sparks to which they are closely related.

Spark bursts will vary in intensity, size, number, shape, and distance from the wheel or from the end of the carrier lines. The spark burst, that is, the "carbon-spark," is the most useful characteristic of the spark picture, since variations in the number and intensity indicate changes in the carbon content.

Steels alloyed differently but with the same carbon content are not always so easily identified. Most of the alloying elements have some influence on the spark picture. They may affect the carrier lines, the bursts, or the form of characteristic sparks. Their effect may be, for example, to retard or to accelerate the carbon spark, or to make the carrier line lighter or darker.

The burst is the characteristic spark of carbon. Other elements have distinctive characters. One of the most easily recognized of all the characteristic sparks is that of molybdenum, which appears as an orange colored spear point on the end of every carrier line. Other features of the molybdenum spark are that the spear points are detached from the carrier lines (see the figure on the next page) and are always present regardless of the length of the lines. Sometimes, when the carbon content is high, the spear point is difficult to distinguish; but, if a decarburized surface can be found, the characteristic spark immediately becomes quite distinct.

Nickel gives a characteristic spark, identified as tiny blocks of brilliant, white light. In low carbon steels (0.10 to 0.20% carbon and 3.5 to 5% nickel) these blocks are located in the spark stream quite near the wheel, but in higher carbon steels they are located in the burst. When present with molybdenum, nickel partly suppresses the carbon spark.

Silicon likewise suppresses the carbon spark to a marked degree. The carrier line from silicon steels of the S.A.E. 9200 series is much shorter than from a plain carbon steel of the same carbon content, and generally ends abruptly in a white flash of light.

The dull red spark of high tungsten steels is well known to all who have dressed high speed steel tools.

Cabinet and Other Equipment

A substantial wooden cabinet, about 40 in. long, 36 in. wide, and 36 in. deep, will be quite suitable for training men and for use.

It should be placed on top of a bench or table at convenient height, and where no direct light will strike either the operator's eyes or the inside of the cabinet. The inside should be stained a flat black. It should contain an electric light with a convenient switch.

The grinder may be mounted in the left front of the cabinet, and should throw a spark stream across the front of the cabinet at right angles to the operator's line of vision.

The Grinder — The grinder should have a peripheral wheel speed of not less than 3500 ft. per min.

For light grinds made on parts in production, use wheels of small diameter. If the operator is not to be handicapped by unnecessary fatigue, the weight, bulk, and balance of the grinder are important considerations. Portable grinding equipment of approximately 7 lb. with the weight well distributed has been found very satisfactory. The shaft bearings should be readily replaceable.

Grinding wheels should be rather coarse and very hard and approximately $1\frac{1}{4}$x$\frac{3}{8}$x$\frac{1}{4}$ in.

Goggles — Eye protection is most important both for avoiding injury from steel and emery particles, and for minimizing the effects of certain light rays. Goggles for spark testing have been developed by some of the optical companies which satisfy these requirements.

Standard Samples can be prepared from bar steels, the analyses of which are known and recorded. A convenient size is 1 in. diameter and 3 in. long. One end should be stamped with the identification marking for the steel and a sample number.

Samples should cover as wide a range of chemical compositions as possible to permit the operator to familiarize himself with the manner in which the character of sparks is affected by various carbon contents and alloying elements.

For training purposes, a dozen or more samples should be cut from bars of the material upon which the spark tester will do most of his work. For example, if experience in identifying the molybdenum spark is desired, a dozen pieces

of S.A.E. 1020 and a dozen of S.A.E. 4615 of like size and appearance will be useful. These standard samples are consulted only as a means of verifying the correctness of the classification of the "unknown" samples.

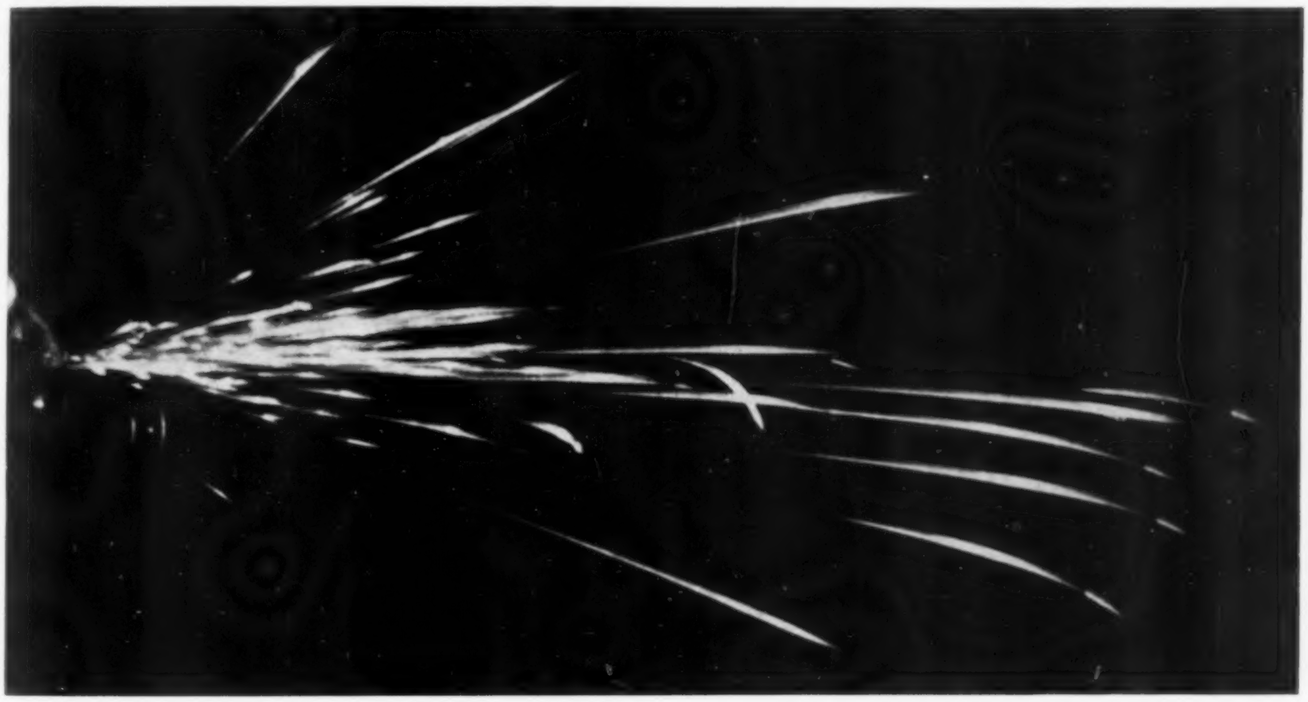
Personnel — It is advisable to select an alert man whose eyes are sensitive to light. He should have a fair knowledge of the composition of various steels.

The operator should be given every opportunity to practice his art. Given the necessary physical and mental attributes, a spark tester's efficiency becomes a matter of experience. The more rapidly that experience is acquired, the sooner he will be available for duty.

Testing in the Plant — Proper lighting conditions are a very necessary adjunct to satisfactory work in the plant. A strong direct light, either natural or artificial, is a distinct disadvantage. Spark testing should properly be done in a shadow, and against a dark background.

It is advisable to protect the spark stream from heavy drafts of air as this will cause a very definite hooking of the tail sparks, which is apt to be confusing.

Bar and tube stock, carefully racked, can frequently be spark tested without removing from the racks. Similar material in bundles can be spread out on inspection benches. Small pieces of regular size and shape are generally

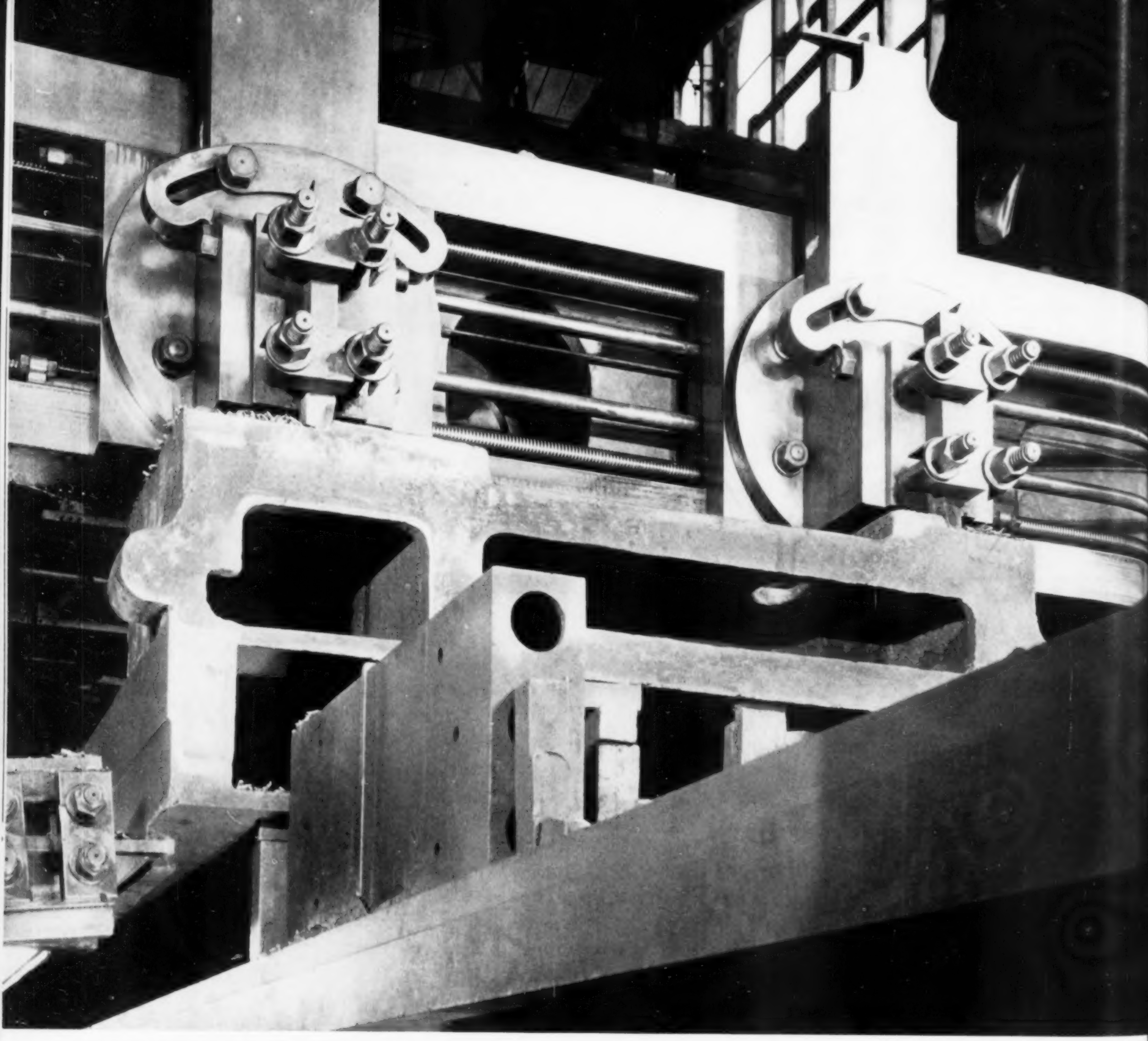


Characteristic Spark of Molybdenum Is an Orange Colored Spear Point Detached From Each Carrier Line

It is advisable to exercise strict supervision of the work. The spark tester should be held at his highest possible efficiency. It must be understood by each operator that his work must be 100%, that not a single piece of foreign steel can be passed in error. Decisions must occasionally be made as to when the test can be used safely, and also when it definitely must not be used. The reputation of the spark test for reliability will depend largely upon the wisdom of such decisions.

placed on work benches. If a large number of pieces must be tested in a limited time, laborers can be used to arrange the parts in uniform rows for the spark tester, so that his time can be applied entirely to spark examination.

Care should be exercised in the case of hot rolled or heavily scaled material to be certain that the spark stream is not from a decarburized area. Bar stock is more safely ground on the cut end, and forgings at the point from which the tonghold was removed.



Modern Tools for Speed and Power

Photograph by
Wm. Sellers & Co., Inc.

DEVELOPMENTS IN CUTTING TOOLS

High Speed, Stellite, Carboloy, Alloy 548

For THE second time in its rather brief history, a meeting of the American Society for Steel Treating has heard a formal announcement of an outstanding event in the evolution of metal cutting tools. The first was at the annual convention in Philadelphia, 1928, when S. L. Hoyt described "Tungsten Carbide — a New Tool Material." The second was at a local meeting in Cleveland last month, when Dr. Zay Jeffries, past president, A.S.S.T., and W. P. Sykes of Cleveland Wire Works, General Electric Co., described "Alloy 548 — A New Metal Cutting Alloy."

In his preliminary remarks, Dr. Jeffries mentioned the view, held in some quarters and popularly associated with the word Technocracy, that a temporary halt should be called upon mechanical improvements until the world is convalescing from its present economic troubles, and he asked whether any man or group ought to go on attempting to learn the laws of nature, and as they were discovered, putting them to work to save human labor. To this he could give only one answer: It is as imperative for the vigorous organization to continue its researches and improvements as it is that the individual eat and exercise. It is an essential part of human progress, and of society as we know it today, that we continue our efforts to improve a product and economize on effort, so that men can have more and finer things in life. This is what is known as progress, and the developments inherent in nature's laws must be brought forward as fast as discovered.

Turning then to a specific instance, he said that history proves that none of the previous discoveries in the art of cutting metals had extinguished any of the principal materials or methods previously in vogue. Carbon tool steel, air hardening steel, high speed steel, stellite, cemented tungsten carbides, all were duly commercialized as discovered, and despite the enthusiasts' recurrent prophecies that each new discovery would dominate the entire field, each has found its own place — none is excluding the others.

This point can best be elaborated by comparing high speed with high carbon tool steel. The latter is the foundation material of the art. Instead of long since having succumbed, Dr. Jeffries found that there was more of it made in 1929 than in 1900, before high speed was commercialized. Upon its introduction, high speed was found to be a more expensive material; furthermore, in certain work it would not perform as well as the old tools, or maybe just a

little better. Consequently, carbon tool steel maintained much of its old ground. What high speed steel really did was to make its own place by generating a new art, the art of rapid turning and cutting, and a whole new industry of machine tool builders grew up to supply the demand of this art.

This is no small achievement in itself!

Then came stellite. At the start this material did not have the advantages of tool steel, for it is a cast material, not forgeable, and reached the buyer only as finished tools. Yet it performed so much better than either carbon steel or high speed on some jobs that the funeral oration was said over the older tools.

It is, of course, well known that these cast tools are not used to the exclusion of others. They did find their own place in an important part of the cutting field, where they are the preferred materials. This restricted use is not because they have not been improved; they have. "Stellite — J" is a very splendid material. But at the same time, high speed was also being improved; first by addition of vanadium, then by addition of cobalt for hogging work, and lastly and most recently by still further increasing the vanadium and the carbon. Heat treatment has also been refined. Thus the relative balance of excellence was maintained.

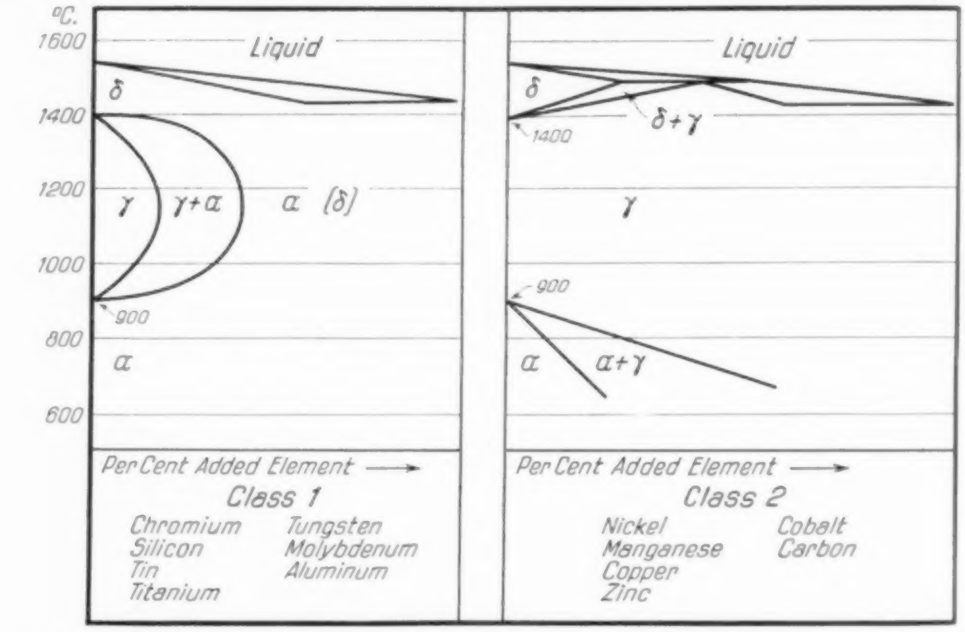


Fig. 1. Schematic Equilibrium Diagrams of Alloy Systems; One Family Restricts the Gamma Region, and the Other Extends It

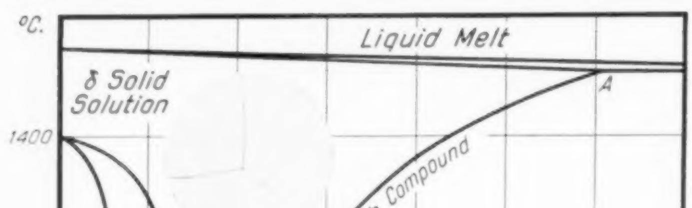


Fig. 2. Iron-Tungsten Equilibrium Diagram. Insets show microstructure of slowly cooled alloys containing 7% and 30% tungsten respectively

Handicapped by Stunts

Normal development of the cemented tungsten carbides, such as Carboloy, Firthite and Widia, was seriously hampered, in Dr. Jeffries' opinion, by the emphasis once placed on the stunts that could be done with them. They could cut glass, electric carbons and insulations, chilled iron, austenitic alloys, stellite! They took the metallurgist's fancy, and were tried on the hardest job in the shop; in many in-

stances the application was so ill-advised that several expensive tools were broken up. At that place the new material was forthwith abandoned as useless.

Fortunately, a considerable number of men started in a saner manner, studying the new cutting material, finding where it was best fitted, where most economical, and applying it there. Only through continuous cooperation with such plants was the carbide industry able to launch itself and to find its place. This, contrary to predictions, is not in stunts.

In numbers of places the material is cutting "uncuttable" substances, and such operations would be sadly handicapped (if not impossible) without it, but the total number of carbide tools absorbed for such duty is only a small proportion of the total sold today. Most of it is used in cutting soft gray cast iron and in the manufacture of drawing dies (a lowly application). As such it has definite advantages. For instance, on cast iron compressor cylinders for an electric refrigerator, only four can be bored with a high speed steel tool per grind, and each of them has a measurable taper; with cemented carbide tools 400 can be bored before the work is out of size, and none of them have measurable taper.

Dr. Jeffries mentioned recent improvements in the chemistry of the carbide tools. Tungsten carbide with cobalt binder is by far the most important variety, but sometimes the tools work better on soft steel if a sizable percentage of tantalum carbide is also present. It is hard to choose between the tantalum-tungsten mixture containing more than 50% tantalum carbide and those containing mostly tungsten carbide; each will do a few things that the other can't. For some time a small percentage of titanium carbide has also been added to steel-cutting tools; it has a certain influence on the "loading" of the tool — that is, the welding of the chip to the nose. More recently a considerable percentage has been added with good "stunting" results for steel turning, and such tools are being vigorously promoted in England. Changes in the binder, as by using some nickel in place of the cobalt, have also received much attention. Other hard compounds have also been tried, but at present are of very minor importance. This is not to say that these improvements are of no value; rather it is true that each successful experiment adds something to the capabilities inherent to the base material — tungsten carbide plus cobalt — and so enlarges the useful possibilities.

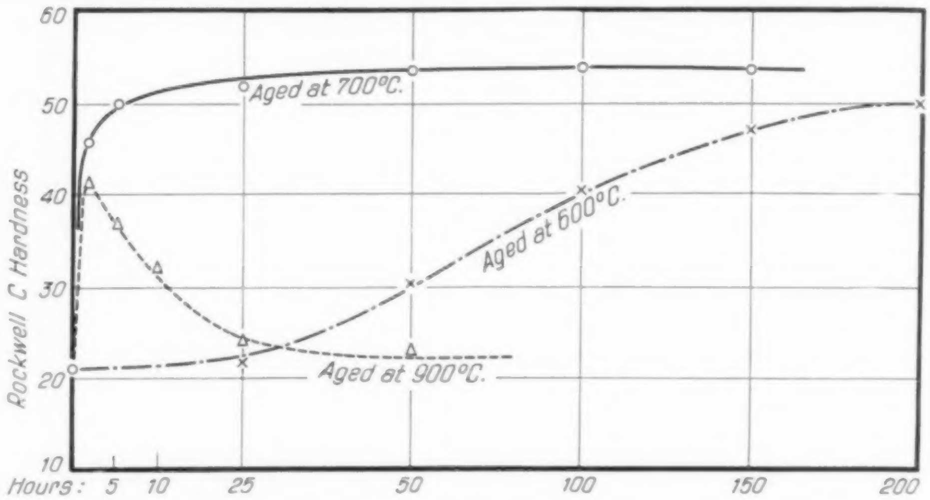
Its future may be judged from the statement that more of the tungsten carbide tools were sold in 1932 than in 1931, even though the automotive industry (the largest user) was off 40%. Dr. Jeffries also recalled a remark he made a couple of years ago to Dr. Mathews, that despite the new tool materials, there would be more high speed made and sold in 1939 than in 1929. Each will have its place. The introduction of a material like cemented carbide enriches the whole field of mechanics, makes more things machinable, and machines cheaper.

Now comes a new cutting tool, "Alloy 548," or rather a family of alloys, principally of iron, tungsten, and cobalt. It was developed by W. P. Sykes in Cleveland; important improvements by C.P.Miller of Romiley, England, were also made. It functions best as a carbon-free alloy, or at best with very little carbon. Its hardness is not inherent, as cast, but is developed by quenching and by aging. It can be melted, cast, forged, or rolled, then machined and heat treated for use. In its toughest condition it has considerably higher transverse strength than cemented tungsten carbide. It can be sold for about $4.50 a lb. It therefore can be made into whole tools and cutters, although brazed inserts may prove economical.

Dr. Jeffries was very chary in quoting specific performances of the new tools. His plea was for an intelligent trial, and for the experimenter to avoid stunts. Laboratory tests and preliminary tests in production show that Alloy 548 has qualities midway between high speed and cemented tungsten carbide — a field where many tool experts have said a gap now exists. The speaker was strong in his opinion that it would find its own place and not usurp the fields of the other well-known materials.

Many heats have been made, and the excellent properties are readily duplicated. That is to say, the material is not overly sensitive — quite a wide range in composition and treatment will give the desired hardness and cutting qualities. As to the exact composition, it will be necessary to find the best balance between

Fig. 3. Age Hardening Curves for Iron-Tungsten Alloy, Free of Carbon



cheap iron and expensive tungsten and cobalt in the alloy to give the most economical performance in various applications.

As far as tests show it appears that Alloy 548 will cut only those things that high speed will cut; it seems to be somewhat better than high speed tools when cutting the harder steels, but becomes steadily better as the job becomes easier — that is, on soft steel or cast iron.

Speeds up to 350 ft. per min. have been in production, but the correct balance between speed and tool life will have to be struck for each successful application.

Mr. Sykes' account of the metallurgical development now follows.

NEW METAL-CUTTING ALLOY

By W. P. Sykes

AT THE Cleveland Wire Works we first came upon the unusual hardening characteristics of these alloys while investigating the effect produced by substituting cobalt for some of the iron in the carbon-free alloys of iron and tungsten with which we were more familiar. (A systematic report on the latter system had been presented before the American Institute of Mining & Metallurgical Engineers, Feb., 1926.)

Since the ternary alloys combine some of the hardening properties of both iron-tungsten and iron-cobalt systems, it will perhaps be most satisfactory to describe them by reference to these two families from which they sprang. In other words, we may trace the inherited characteristics back to the parents. In fact, one of the most vital factors in the hardening powers of the new alloy is derived from the transformation in iron itself, so that we might say that this characteristic is from a grandparent.

One of the critical points in pure iron occurs at about 900° C. (1650° F.). When cooling through this temperature the iron undergoes an allotropic change, or atomic rearrangement which results in the break-up of the crystals of gamma iron and the formation of a new set of small crystals or grains of alpha iron. If the cooling is very rapid, as in iced sodium hydrate solution, the change cannot be suppressed, but the growth of these new grains is in some measure prevented, and the microstructure at room temperature is marked by relatively small grains, as compared to iron cooled slowly. This grain refinement in pure iron is accompanied by a moderate hardening.

If the quench is extremely drastic, as in cold mercury, a further increase in hardness is noted, and the resulting microstructure is marked by sets of parallel lines or needles, which suggests that in the atomic rearrangement at 900° C. certain crystalline planes and directions are involved. This type of structure recurs in the new cutting alloys.

Knowledge has progressed to the point where it is possible to classify some of the common alloying elements into two groups, on the basis of the effect produced by the element upon the critical points of iron. The first sketch on page 30 shows one such method of classification.

It will be noted that the elements in one class, which includes tungsten and molybdenum, restrict the field of temperature and composition where the gamma form of iron can exist.

This action was first detected by noting the change in temperature of the critical points produced by the addition of the second element. For example, 3% of tungsten depresses Ar_4 to 1335° C. and raises Ar_3 to 936°, and in an alloy of iron containing more than 6% tungsten there is no transformation or grain refinement throughout the range between room temperature and the melting point. For this reason quenching will not harden a 6% alloy.

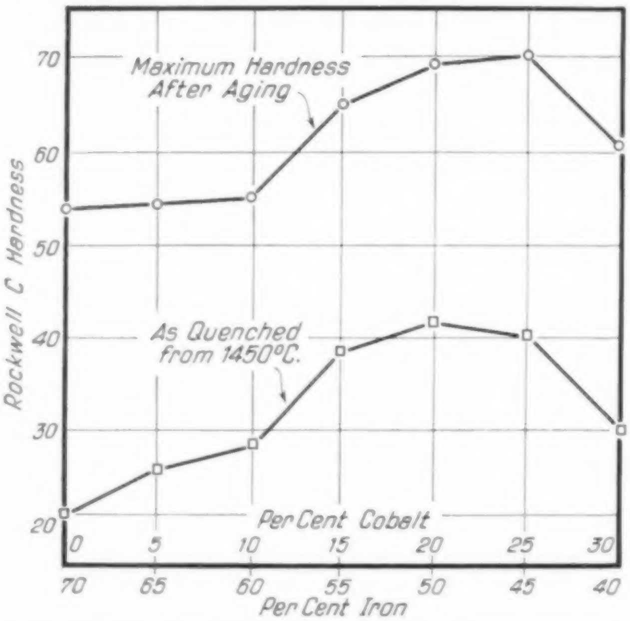


Fig. 4. Effect of Cobalt on the Aging of Iron-Cobalt-Tungsten Alloys with 30% Tungsten

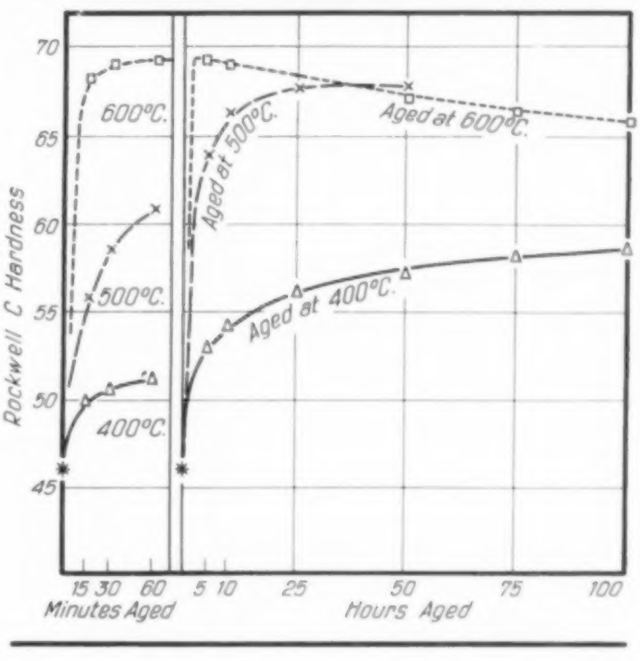
On the other hand, the elements of the other class, which include carbon, nickel, and cobalt, extend rather than constrict the gamma field. The structures found in such alloys after quenching from above the transformation range are characterized by the acicular microstructure commonly associated with martensite. Such structures are always accompanied by increased hardness.

Since we are interested primarily in the hardening properties of the carbon-free alloys let us return to the iron-tungsten system, more accurately sketched in the lower diagram on page 30. It is possible to put some 30% tungsten into solid solution in the iron by quenching from 1500° C. Presence of this much tungsten in solid solution raises the Brinell hardness to about 180 from the Brinell 70 of pure iron. This action is in line with observations on other solid solutions; the increased hardness given by copper to aluminum, for instance, is nearly proportional to the number of atoms of copper per hundred atoms of aluminum.

Fortunately, this moderate effect can often be increased by precipitation hardening; the Brinell number of iron-tungsten alloys can thus be increased to about 400.

Precipitation hardening is possible because of the fact that iron dissolves 30% of tungsten at 1500° C. (2730° F.) but only some 6% at 500° C. (930° F.). As the temperature of the solid alloy falls below 1500° C. some of the tungsten tends to separate from the iron in the form of crystals of an iron-tungsten compound. The amount of tungsten soluble in the iron at a given temperature is indicated in Fig. 2, page 30, by the curve *AB*, and if the alloy is cooled slowly the precipitated tungsten compound takes the form of sizable crystals. The mechanism of the reaction is quite similar to what happens when a high carbon tool steel is cooled after annealing.

Fig. 5. Age Hardening of Iron-Cobalt-Tungsten Alloys. All were quenched from 1200° C.



When the precipitate exists in this coarse form it has little effectual hardening action. However, by quenching such an alloy from 1500° C. to retain the tungsten in solid solution and then reheating at 600 or 700° C. (1100 or 1300° F.) the iron-tungsten compound separates from the solid solution in a very finely divided state, and the hardness of the alloy is increased to its maximum of about 400 Brinell or Rockwell 53-C. The quenched alloy has a single-phase structure, and looks like the left-hand one on Fig. 2. Reheating at 700° C. fails to produce visible crystals within the primary grains, but the latter darkens quickly in the etching reagent (a characteristic of troostite in quenched and tempered steel). Some slight precipitate can be noted at the boundaries of the large grains, and this makes for brittleness in this age hardened iron-tungsten alloy.

Precipitation hardening occurs in a large number of alloy systems, including the iron-tungsten and the iron-molybdenum systems. The temperature at which it begins is a characteristic of the alloying element.

Figure 3 on page 32 shows the way the quenched 70:30 iron-tungsten alloy hardens. If it is aged at 600° C. (1100° F.) it will not reach a maximum after 200 hr. At 700° C. (1300° F.) it hardens rapidly and remains fairly constant between 25 and 150 hr. This property of retaining hardness at high temperatures is known as red hardness and is, of course, a requisite for tools used at high cutting speeds, where so much heat is generated by the work and friction.

Turning from the simple iron-tungsten alloys, one of the first effects observed when cobalt is substituted for a part of the iron is a marked increase in hardness, both in the quenched state and after aging. Curves of Fig. 4, page 33, show the effect of substituting cobalt for iron by increments of 5% in a base alloy containing 30% tungsten. After the cobalt has replaced 10% of the iron by weight, the hardness values increase rapidly. At 25% cobalt the so-called secondary hardness (or hardness developed after aging) has a maximum of Rockwell C-70 to C-71. This represents a remarkable increase over the Rockwell C-53, which was the maximum developed in the simple iron-tungsten alloys.

The alloys containing cobalt, moreover, begin to harden at about 400° C. (750° F.). At 500° C. or 600° C. the increase is extremely rapid. While the hardness thus developed is somewhat less permanent at elevated temperatures than is that of the iron-tungsten alloys, it is nevertheless remarkably resistant to extended heating at 600° C. (1100° F.) — see Fig. 5.

While the information on the ternary system is as yet incomplete, it would appear that the addition of considerable cobalt extends the gamma field in such a way that the alloys now to be discussed are gamma solid solutions at temperatures above 1000° C. On cooling, the allotropic transformation from gamma to alpha occurs (essentially a change from face-centered to body-centered space lattice). During this first change no precipitation of excess constituent occurs — only upon aging does a tungsten-rich compound appear. Hence these new alloys have a second source of hardness, namely, grain refinement of the matrix.

A study in contrasts is afforded by the curves in Fig. 6 below, which illustrate the changes in hardness observed in four different materials which were first treated to develop their maximum hardness, then heated together at 600° C. (1100° F.) over a period of 50 hr. This diagram emphasizes one outstanding difference between the carbon-bearing ferrous alloys, including steels, and the carbon-free ferrous alloys typified by the iron-tungsten and iron-molybdenum series.

The effect of carbon added to the latter two alloys is to somewhat increase their hardness when quenched, and to render the secondary

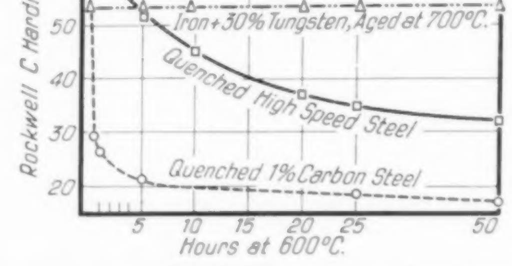


Fig. 6. Change in Hardness of Various Tool Alloys, Hardened to Maximum by Treatment Noted, and Then Held at 600° C. (1100° F.)

hardness (or red hardness) less permanent at temperatures above 500 or 600° C. (1100° F.).

Finally, the group of microstructures alongside illustrate the ternary iron-cobalt-tungsten alloys after various treatments.

The top one contains 20% tungsten, 30% cobalt, and 50% iron, and is the coarse-grained solid solution resulting from heating at 1300° C. (2375° F.) for 1 hr. and then quenching. The markings within the grain result from the transformation of the gamma solid solution which occurred during the quench. Hardness is C-40.

The same alloy, as forged, reheated to 1200° C. (2200° F.) for 15 min. and quenched, develops slight markings of martensitic structure in the solid solution, shown well in the second photomicrograph. Note also the undissolved tungsten-rich constituent (dark particles) which has been shattered and elongated by the forging operation. Its hardness is C-45.

If this piece is then reheated to 1100° C. (2000° F.) for 15 min. and quenched, the structure of the alloy is further refined, and the hardness is C-48. See the third view.

By aging at 600° C. (1100° F.) a finely divided precipitate has formed in the martensitic areas. The acicular form of the solid solution is visible, while the general darkening of the field upon etching is characteristic of a highly dispersed precipitate. Here, again, we see some of the tungsten-rich constituent (now white, not etched) remaining undissolved during the brief heating at 1100° C. This sample represents the result of combining two methods of hardening, that is, (*a*) grain refinement of ground mass by quenching through a transformation and (*b*) precipitation hardening. The result is a hardness of C-61.

The last one of the micros shows the alloy as forged, annealed at 1100° C. (2000° F.) for 10 hr., and cooled rapidly. Its hardness is C-46 and represents the most easily machinable state, as the tungsten-rich phase is well spheroidized.

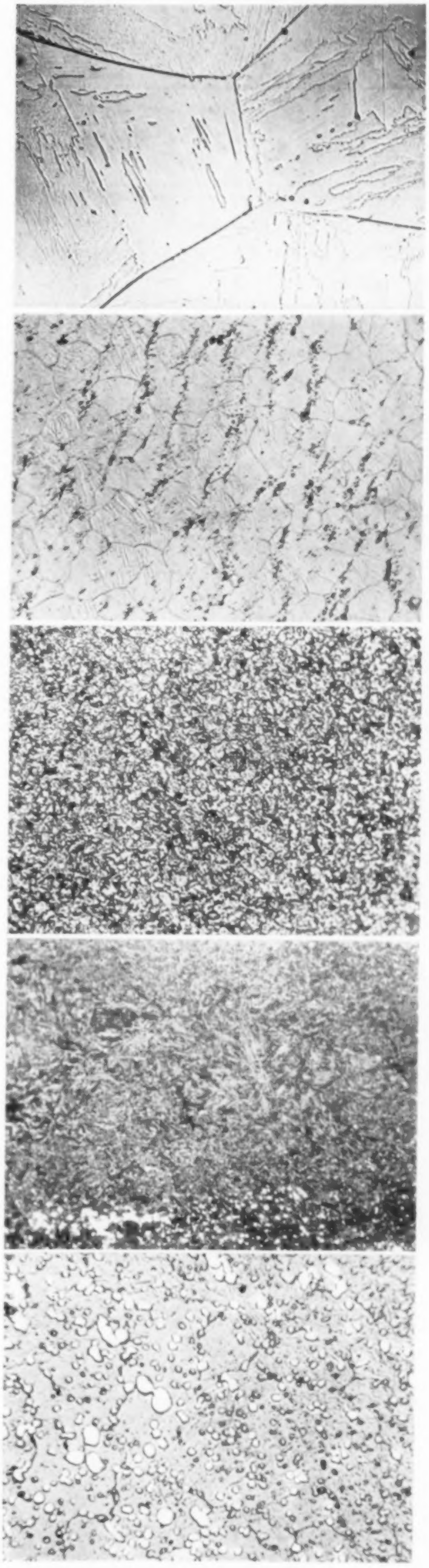


Fig. 7. Representative Microstructures of Iron-Cobalt-Tungsten Cutting Tools Known as Alloy 548

(a) Quenched from 1300° C. 200 ×. Hardness C-40
(b) Forged alloy, quenched from 1200° C. 100 ×. Hardness C-45
(c) Above; refined from 1100° C. 500 ×. Hardness C-48
(d) Above; aged at 600° C. 500 ×. Hardness C-64
(e) Alloy in machinable condition. 1000 ×. Hardness C-46

HARD STEEL PIVOTS AND BEARINGS

precision scales require advanced metallurgy

By W. J. Burr
Metallurgist
Toledo Precision Devices, Inc.

WEIGHING is an art so old and so commonplace that probably there is little conception of the amount of precise and delicate work involved in the manufacture of a modern scale. Today scales are being adapted to an almost limitless number of special measurements. It is a long road from the simple balance to a weighing machine with an electric eye to control batch weights, or one to measure wind resistance on an airplane.

The reader is doubtless familiar with one type or another of industrial scales; therefore no attempt will be made to describe the construction in detail. They have a multiplication of levers to reduce the load so that the load to balance (whether on beam or dial) is but a fraction of the load to be weighed. Such a design economizes space and permits adaptations impractical with beam balance or simple spring scale.

The general practice is to employ cast iron for all heavy structural parts, such as the frame, housings, and levers, although in some very large installations cast steel and rolled shapes are employed. Levers for scales of the lighter capacities are soft gray iron; it is better to use high test gray iron castings for the levers of the heavy scales. Today these levers are scientifically designed, eliminating weight where not required and allowing generous sections where stresses necessitate. To insure permanency of dimensions, levers are aged to a temperature of 900 to 950° F.

Treatment of Bearings and Pivots

Bearings and pivots are to a scale what jewels are to a watch. They must be *right* before any other refinements are made, for a scale is no better than its bearings and pivots.

These parts are usually made of a hardened steel. (In small scales agate bearings are used to secure a minimum of friction.) Practice at Toledo Scale Co. calls for a 1% carbon steel for both bearings and pivots wherever practical. Some, due to their shape, lend themselves better to a carburized and hardened steel; low carbon, medium manganese steel is then used.

Nearly all of the high carbon stock is bought in bar length, cold drawn to shape. Bearings usually have a V-type groove of 120° angle on their working surface, while the pivots

Pivots Usually Are 1 In. to 6 In. Long, Although a Large Track Scale Requires 36-In. Pivots

are pear-shaped, in most instances with a knife-edge angle of 60° to 70°, though some are as sharp as 30°. After the parts are sawed off on a gang saw or an automatic (used for pivots with tapered shanks) the bearings are drilled midway between the bottom of the V and the lower face for the insertion of a supporting pin. Any decarburized skin and surface scale is removed from the working faces and they are then ready for heat treating.

Since the variety of sizes and shapes is considerable and the actual tonnage small, heat treatment of these parts lends itself better to the batch type salt bath or box furnace than to a continuous furnace. We use Westinghouse pot-type and box-type furnaces with heating elements in every face including the door. Drawing is done in a Homo furnace. Each has automatic temperature control.

The heat treatment may be likened to tool hardening on a production basis. Each part is a particular tool in itself and has to be handled as such. Smaller bearings (up to 1/2 in. square) are hardened from the salt bath in baskets in 5 or 6-lb. lots. All taper-shank pivots are handled similarly. The salt baths carry sufficient cyanide to prevent decarburization.

Larger bearings (say 7/8 in. square by 1 1/8 in. long) are quenched from the box furnace — either individually with the V over a spray, or strung on rods and quenched by immersion. The use of such rods guards against cracking where the pin hole is close to the V.

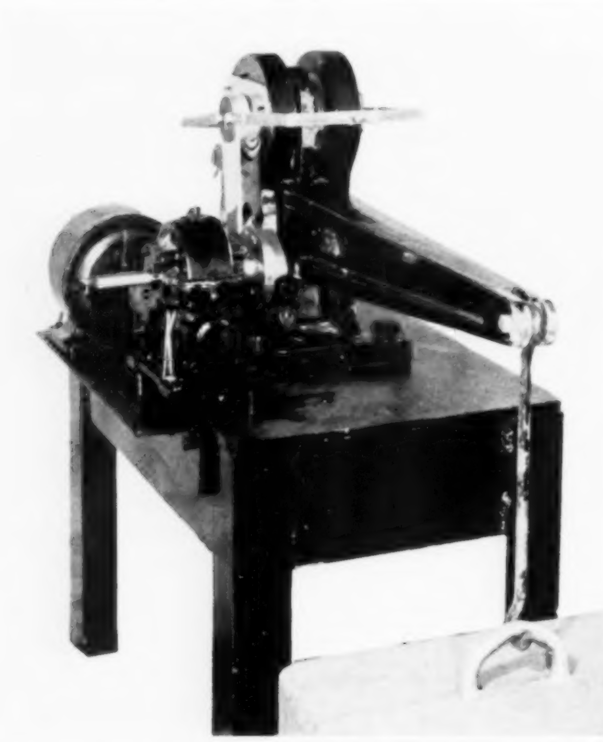
Temperatures must be adhered to very closely in treating bearing parts, as most of them have an uneven distribution of mass, with an abundance of sharp angles and corners. As a rule, the smaller sizes are quenched at 1380 to 1400° F., while for the larger ones the temperature is raised to 1420°.

Pivots present different problems. Long pivots, where the knife edge is engaged only on the ends, are quenched end-for-end from a lead bath, suitable holding fixtures being employed. Where the knife edge is in the center and the supports at both ends, we generally resort to a carburizing steel, copper plating all but the side of the knife edge to eliminate warpage and to facilitate straightening.

After hardening, bearings are drawn at 325°, while pivots are given a higher draw of 375°. The higher draw has a two-fold purpose — to insure that the pivots are no harder than the bearings and also to give them extra resistance to chipping under load.

Both pivots and bearings are given a finish grind, with extreme precaution against wheel drawing — an ever-present hazard on such small parts. All grinding is done under a copious flow of coolant. Inspection (100%) follows grinding. Special adapters permit testing for hardness very near the line of contact. The bearings will give Rockwell C-62 to C-64, while the pivots have a minimum of C-60.

While the primary requisite of a knife edge



Machine for Oscillating Pivots Under Loaded Bearings to Determine Wear or Mushroom Effect

is hardness great enough to resist deformation to any marked degree under heavy loads, it is necessary at the same time to avoid brittleness. Loads on pivots vary from a few pounds up to more than 6,000 lb. per linear inch. The resulting stresses on the very edge, of course, are enormous.

To determine the behavior of pivots and bearings under service conditions we built a machine to produce a large number of stresses in a relatively short period of time. As the above illustration will show, it consists principally of a long lever carrying a bearing at the fulcrum and heavily weighted at the end of the long arm. A carriage directly under the bearing holds the pivot. The pivots are oscillated in the bearing by means of a motor and gear reducer. A cam arrangement also varies the amplitude of oscillation anywhere from 0 to 7° either side of center. (In actual scale service the amount of oscillation does not exceed 2° with the heavier loaded pivots.) The speed is 180 oscillations per minute.

Numerous steel combinations have been tested on this machine, and important results secured. Test pivots were made with a 70° angle and a sharp knife edge not exceeding 0.0002 in. width. Bearings were 120° V-type, with a very small radius at the bottom angle.

A summary of the tests shows that a given loading upsets the edges approximately in proportion to the hardness of the steel pivot. A static load of 5000 lb. per linear in. on a pivot with a Rockwell hardness of C-58 to C-62 crushed the vertical dimension 0.003 or 0.004 in. Due to mushrooming, the width of the flattened edge was then on the order of 0.006 to 0.009 in. The bearings, if a little harder than the pivot, showed but a very slight marking.

Wear on the knife edge occasioned by oscillating through 2° and even up to 3° had but little effect; even over a prolonged test of a quarter of a million oscillations the additional deformation was only 0.001 to 0.002 in. When the movement was over 4° the wear was rapid, and as a rule was accompanied by chipping. Likewise, if the pivots were less than C-58 hard, the deformation increased.

The 1% carbon steel functioned very satisfactorily. Carburized and hardened S.A.E. 1020 or the medium manganese, low carbon type of carburizing steel stood the static loads very well, but had more tendency to chip under wide oscillation. Alloy carburizing grades, notably chrome-vanadium steel S.A.E. 6115, were better in this respect. High carbon chrome-molybdenum stood up exceptionally well — in fact, somewhat better than the straight carbon.

Stainless steel functioned about the same as the plain carbon at comparable hardnesses. The medium carbon, 13% chromium type, being softer than the 18% chromium, 1% carbon type, did not give as good service as the latter.

Tungsten carbide was only tried in small sizes for precision scales, but in these it held a perfect edge. No attempt was made to test it in the form of larger pivots as the cost of production would be prohibitively high, in view of the excellent service capable of being delivered by the carbon and alloy steels. Pivots made with welded-on edges of stellite or other special non-ferrous alloys chipped under heavy loads.

Nitrided pivots were unsatisfactory due to chipping, although such bearings are exceptionally good for the lighter and intermediate

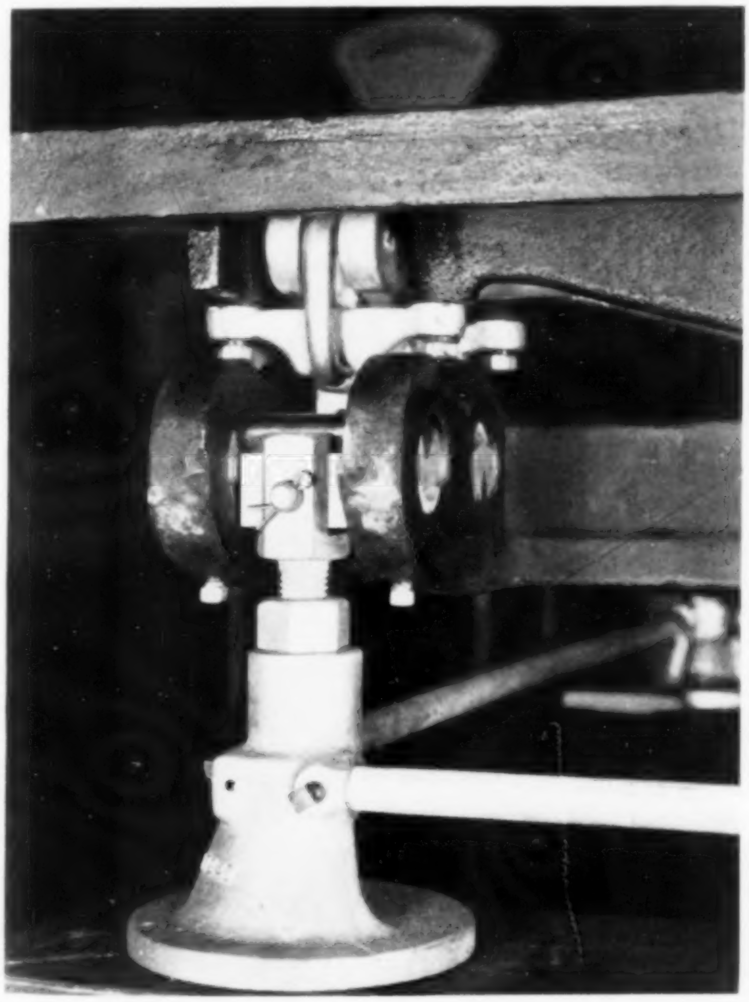
loads. This is especially true if the steel nitrided is of the high speed or special alloy type which withstands nitriding temperatures without softening the core.

In the past the universal practice has always been to insert the pivots in the molds and cast them in the large levers — indeed, even in some of the smaller types. Heat treating was done after driving out the cast-in pivots; the smaller pivots were heat treated in place. This was cumbersome, and there was always the danger of cracking the hardened pivot when driving it back into the lever, or of incorrect treatment of those hardened in place.

Pivots now, except those with taper shanks which are readily driven into reamed holes in the levers, are held by containers of a special butterfly shape mounted in the levers. This permits quick assembling (or removal if occasion demands). These butterfly sections are bought drawn to shape. They are S.A.E. 1020, carburized and hardened, as they take side thrusts formerly carried by the bearing. They are shown clearly in the view on this page.

All of the foregoing has been a description of parts going into the base of the scale. In the head mechanism of dial indicating scales there are several features that will bear description, for the provisions must be most exact.

The shaft which carries the indicator pointer is mounted in ball bearings. This shaft also carries a pinion which is meshed with a rack. The whole mechanism is in turn connected to cams which carry the pendulums. The cams themselves have steel ribbons attached to them, the other ends of which are connected with the platform levers through intermediate levers, rods, and check links.



Assemblage of Pivots and Bearings, the Latter Held in Place in Cast Iron Lever Beams by Butterfly Containers

The ball bearings are special. No conventional retainer is used, the balls being held in the race by thrust plates. Balls are of the ordinary type; the races and thrust plates are carburized, hardened, and polished to reduce friction to the minimum at this point.

The shaft is made of drill rod, hardened only at the engagement points with the bearings. This is accomplished by heating the shaft in lead to just above the bearing shoulder and quenching. Then the small square end, on which the indicator hand is pressed at assembly, is immersed in lead to draw it. Each end of the shaft has to be treated this way.

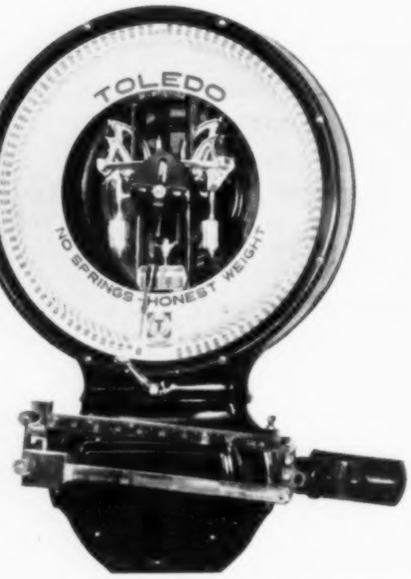
Midlength of the shaft is a pinion made of cast gear bronze. It meshes with a rack made from hard rolled sheet brass; the teeth are cut parallel with the direction of rolling to eliminate warpage. Tooth contours of both pinion and rack are very accurately cut, as there can be no lost motion in either direction. Should there be, the indicator hand would not cut the line of every graduation around the dial.

Cams are made of manganese

bronze cast in plastic molds to insure smooth surfaces.

Two kinds of metal ribbons are used, one an imported Swedish spring steel and the other a cold rolled stainless steel of the 18-8 type. The Swedish ribbons are rolled to 0.002 and 0.004 in.; the stainless to 0.004 and 0.007 in.

Cold rolling of these stainless ribbons was no mean accomplishment in itself. The plant which processed them used the recently developed Steckel cold mill, and was able to develop about three-quarters of the "spring" of the oil-tempered carbon steel ribbons. In gages smaller than 0.004 in. they are not satisfactory, but when the 0.007-in. ribbons are placed over cams having a generous radius, they are all that can be desired, and avoid the corrosion from which carbon steel ribbons unfortunately can not be protected.



Head Mechanism Contains Many Precise Parts Made of Special Alloys Ranging From Duralumin to Spring Steel Ribbon

Some of the Swedish ribbons, where service conditions require it, are cadmium plated for protection. Care then has to be taken to remove the effect of hydrogen absorption after cleaning and plating. Moderate baking will remove most of this brittleness.

Another interesting part that works in conjunction with the head mechanism is the dash pot. This is of conventional design, except that the plunger carries a thermostatically controlled valve. As an ordinary straw paraffin oil, having a viscosity of 75 to 85 at 100°, gives the most satisfactory service, it is advantageous to compensate for changes in the dash pot action due to changes in oil viscosity over a temperature range of about 100°. This is done automatically by a thermostat — a bimetallic strip formed as a tension plate over an orifice in the plunger.

Lithography also plays a very important part in scale manufacture. Most dial charts or faces are printed from stone etchings on special white-surfaced steel sheets. Some charts, notably those used for cylinder scales, are made of anodic treated aluminum sheet; the printing is done directly on the oxidized aluminum surface, and a clear lacquer coat sprayed on to protect the markings.

One special chart, used on a printing mechanism which automatically prints weights on tickets, is an etching itself. The material is sheet duralumin. There are hundreds of figures on these charts and the width of line on the markings is only about 0.010 in. These figures must be etched in relief to a depth of 0.006 in. Ordinary brass or zinc etching is common practice with the lithographer, but the aluminum alloy sheet presents a different problem. Antimony chloride, in a solvent which does not permit the formation of oxychlorides, has been found to be most suitable. However, the perfection of an etching still depends primarily upon skill.

Chromium plating is used extensively throughout the scale, both in the form of plate for ornamentation and of hard chromium plate. An example of the latter is on tare beams over which the poises slide. This plating is done directly on the base metal, which is hard rolled brass.

As scales are exposed to almost every conceivable kind of atmospheric condition, protective coatings of all sorts are employed. The outside finishes of the different scales may vary, but for the most part are either lacquer or porcelain enamel.

From the above it will be understood that precision scale manufacturers are adapting the various advances in metals and machine tools to their own specialized purposes with the greatest satisfaction.

Product Re-Design is Affecting Everything made in this Country

"Good Looks" . . . only one Angle of Re-Design

It is of little value to re-design your product —making it good-looking—if it is obsolete functionally. Thorough product re-design begins with the choice of the basic material which must fit the functional needs of the finished product. I have found that where those needs are great tensile strength coupled with extreme lightness and resistance to corrosion, Alcoa Aluminum fits in a vast majority of cases. It fits for products as widely variant as Moving Vans, Street Lighting Towers, Telephones, Chairs, Steam Jacketed Kettles, Mine Cars, Airplanes and Wrist Watches.

Russell Wright

These Alcoa Aluminum "Hoppers" are each 21,200 lbs. lighter than old-fashioned cars . . . carry that much more revenue-producing freight.

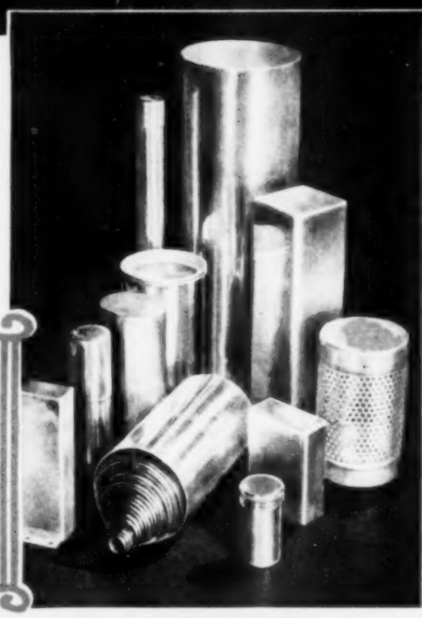
Wrist Watch called "The Akron" because, like the Navy's Dirigible, it is made mostly of Alcoa Aluminum. Only non-aluminum parts are main and hair springs, balance wheel and hands. Including wrist band, watch weighs only 1 ounce . . . is 97% aluminum.

ALCOA ALUMINUM

What Customers want . . . is the reason for the vast shift to ALCOA ALUMINUM

Under the black finish of the new hand set on your desk is *Alcoa Aluminum* . . . the base, cradle, plunger, receiver, transmitter case and diaphragm are all made of Alcoa Aluminum.

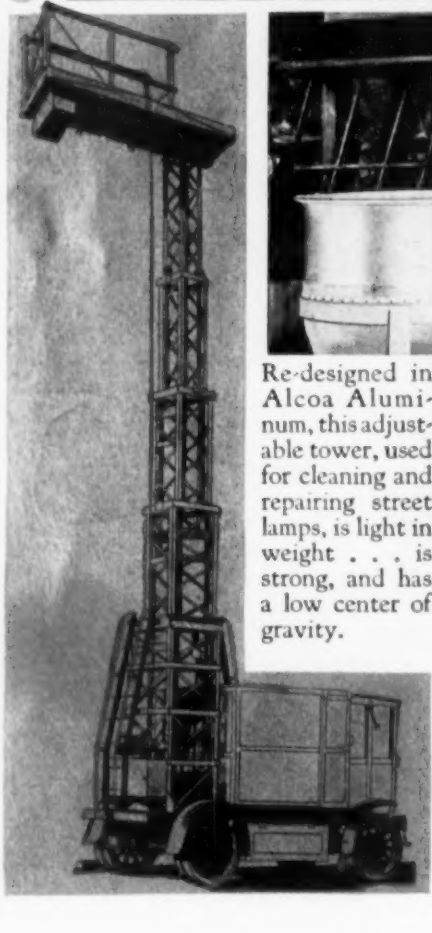
Floor-Waxer die cast in Alcoa Aluminum, bringing big weight reduction of finished product . . . making fabrication easy.



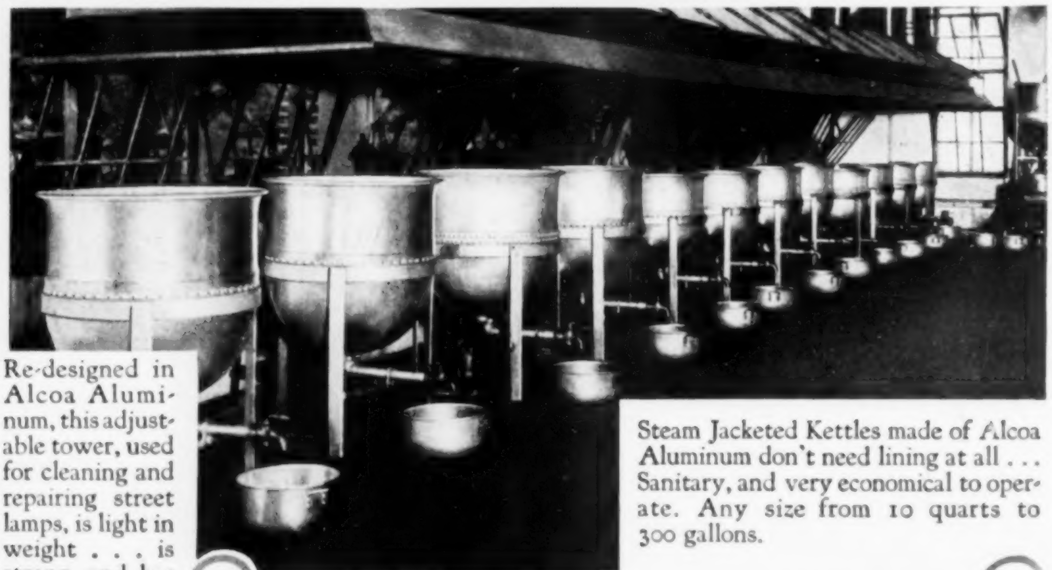
Propellers! Made of the one metal that flies best . . . Alcoa Aluminum. . . . It reduces dead weight, without sacrificing structural strength . . . is non-combustible, shatter and splinter-proof.

Pack anything in Paste Form . . . foods, cosmetics, greases? Then consider Alcoa Aluminum Extruded Jars. Safe in contact with all foods . . . chemically inert . . . add beauty to the package at low cost.

To Catch more Sales, Leaders Bait their Lines with New Design



Re-designed in Alcoa Aluminum, this adjustable tower, used for cleaning and repairing street lamps, is light in weight . . . is strong, and has a low center of gravity.



Steam Jacketed Kettles made of Alcoa Aluminum don't need lining at all . . . Sanitary, and very economical to operate. Any size from 10 quarts to 300 gallons.

What Customers want . . . is the reason for the vast shift to ALCOA ALUMINUM

ETCHING CHARACTERISTICS OF CONSTITUENTS IN ALUMINUM ALLOYS

Constituents	Reagent					
	0.5% HF Swab for 15 seconds, wash in cold water	1% NaOH Swab for 10 seconds, wash in running water	20% H_2SO_4 at 70°C., immerse specimen for 30 seconds, quench in cold water	25% HNO_3 at 70°C., immerse specimen for 40 seconds, quench in cold water	10% NaOH at 70°C., immerse specimen for 5 seconds, rinse in cold water	0.5% HF, 1.5% HCl, 2.5% HNO_3, immerse specimen for 15 sec., rinse in warm water
Silicon	Outlined. Unattacked. Color lightened.	Outlined. Unattacked. Color slightly lightened.	Unattacked. Color lightened.	Outlined. Unattacked. Color lightened.	Outlined. Unattacked. Color lightened.	Outlined. Unattacked. Color lightened.
Mg_2Si	Colored bright blue.	Outlined. Color unchanged.	Action violent. Some particles dissolved, any left have a blue color.	Colored brown or black.	Outlined. Color lightened.	Outlined. Colored blue to brown.
$CuAl_2$	Outlined. Part of pinkish tinge removed. Constituent light and clear.	Outlined. Part of pinkish tinge removed. Constituent light and clear.	Outlined. Part of pinkish tinge removed. Constituent light and clear.	Colored brown or black.	Pitted. Colored light to dark brown.	Outlined. Constituent light and clear.
β Al-Mg	Outlined. Slightly clearer and more watery. Black pits appear in particles.	Not Outlined. Unattacked. Uncolored.	Attacked vigorously resulting in pitting. Some particles dissolved.	Heavy attack, particles grayish and watery.	Outlined. Unattacked. Uncolored.	Heavily outlined. Attacked by pitting.
$FeAl_3$	Slightly darkened. Brown stains appear on large primary particles.	Outlined. Slightly darkened.	Heavily attacked. Particles often dissolved or deeply pitted. Color darkened.	Outlined. Contrast with Al-Fe-Si improved.	Outlined. Colored deep brown.	Outlined. Uncolored. Slightly attacked.
α Al-Fe-Si	Outlined. Not colored.	Outlined. Not colored.	Outlined. Blackened and attacked.	Outlined. Contrast with $FeAl_3$ improved.	Attacked. Blackened.	Heavily outlined. Darkened and roughened.
β Al-Fe-Si	Blackened and attacked.	Outlined. Uncolored. Unattacked.	Outlined. Slightly darkened and pitted.	Outlined. Uncolored. Unattacked.	Outlined. Slightly darkened and attacked.	Outlined. Slightly darkened and roughened.
Al-Mn	Outlined. Slightly darkened.	Attacked. Colored brownish or bluish but coloring is uneven.	Outlined. Uncolored. Unattacked.	Not Outlined. Unattacked. Uncolored.	Colored blue or brown.	Outlined. Unattacked. Uncolored.
$NiAl_3$	Outlined. Colored blue and brown.	Outlined. Darkened slightly. Not colored.	Outlined. Darkened slightly. Not colored.	Outlined. Uncolored. Unattacked.	Colored blue to deep brown.	Colored brown to black.
Al-Fe-Mn	Outlined. Colored brown. (Sometimes bluish)	Outlined. Particles pitted. (Often a rough blue color on a few particles.)	Outlined. Unattacked. Uncolored.	Outlined. Unattacked. Uncolored.	Colored deep brown to blue.	Outlined. Attacked. Darkened.
Al-Cu-Ni	Outlined. Unattacked. Darkened.	Outlined. Slightly darkened. Not attacked.	Outlined. Slightly darkened. Not attacked.	Blackened. Some particles dissolved.	Outlined. Unattacked. Uncolored.	Outlined. Some large particles stained unevenly.
α Al-Cu-Fe	Outlined. Blackened.	Outlined. Unattacked. Uncolored.	Outlined. Unattacked. Uncolored.	Outlined. Unattacked. Uncolored.	Outlined. Blackened. Attacked.	Blackened.
β Al-Cu-Fe	Outlined. Unattacked. Uncolored.	Outlined. Slightly darkened.	Outlined and uncolored. Often show black cores which are probably $FeAl_3$	Outlined. Slightly darkened. Unattacked.	Pitted. Colored light brown.	Outlined. Blackened.
Al-Cu-Fe-Mn	Outlined. Colored light brown to black. Usually appears roughened.	Outlined. Uncolored.	Outlined. Blackened.	Outlined. Unattacked. Uncolored.	Outlined. Uncolored.	Outlined. Colored brown to black.
Al-Mn-Si	Outlined. Colored light brown to black. Usually appears roughened.	Outlined. Usually appears rough and attacked. Slightly darkened.	Outlined. Appears rough and attacked. Darkened slightly.	Outlined. Appears rough. Darkened slightly.	Outlined. Attacked. Color not changed.	Outlined. Slightly darkened.
Al-Cu-Mg	Outlined. Blackened.	Outlined. Colored light brown.	Outlined. Attacked. Blackened.	Outlined. Attacked. Blackened.	Outlined. Unattacked. Colored brown.	Colored brown to black.
$CaSi_2$	Colored blue. Heavily outlined.	Outlined. Color unchanged.	Outlined. Colored blue. Roughened.	Outlined. Unattacked. Uncolored.	Outlined. Blackened. Attacked and roughened.	Colored brown to blue. Mottled.
Al-Cu-Mn	Outlined. Attacked. Blackened.	Outlined. Unattacked. Uncolored.	Outlined. Colored light brown.	Outlined. Unattacked. Uncolored.	Outlined. Attacked. Blackened.	Attacked. Blackened.
$CrAl_7$	Outlined. Unattacked. Uncolored.	Outlined. Unattacked. Uncolored.	Outlined. Unattacked. Uncolored.	Outlined. Unattacked. Uncolored.	Outlined. Colored blue to brown unevenly.	Outlined. Unattacked. Uncolored.
Al-Cr-Fe	Colored light brown. Unattacked.	Not outlined. Unattacked. Uncolored.	Outlined. Unattacked. Uncolored.	Not outlined. Unattacked. Uncolored.	Small particles colored brown to black. Large particles stained all colors.	Outlined. Colored light brown. Not attacked.

File Test Rapid, But Limited to Very Hard Steels

ANN ARBOR, *Mich.* — Since the editorial "Information Wanted About File Testing" appeared in the September issue of METAL PROGRESS, one answer (written by the Nicholson File Co. Research Laboratory) appeared last December. As I have had eight years of experience in file testing in a company that has used this method for many more years, perhaps I can contribute further information.

The simplicity and rapidity of this method of hardness testing are so strongly in its favor that it has been continued at Hoover Steel Ball Co., regardless of the installation of the most modern indentation hardness equipment. In the period of a few seconds the tester can determine the hardness of each tooth of a gear, various surfaces of a ball or bearing, or other hardened parts without injury to the surface. In so doing no elaborate surface preparation need be done to remove all scale, as is necessary with penetration hardness testers. Of course, oil and loose scale must be eliminated, but generally the file will remove enough scale to give an accurate test of hardness, provided the part is held rigidly.

For determination of soft areas or depth of decarburization the hardened parts must be securely clamped in a vise, rather than held loosely in the hand as indicated in the photograph printed in the December issue. This insures rigidity and gives the tester a means of using both hands, thereby controlling his applied pressure and speed of stroke. Under these conditions the file test is much quicker than microscopic examination or other methods of measuring depth.

As pointed out in the other articles, file testing is an art acquired by experience rather than a scientific method, well worked out. The speed of moving the file across the tested object makes a big difference. A girl in inspection was able to wear away hardened balls (Rockwell C-64) by moving the file fast enough, while a man applying a heavy pressure at slow speed had negligible effect on the same material. Ordinarily, hardened parts of Rockwell C-60 will not be cut, while C-58 cuts slowly, and chromium steel parts drawn at 350° F. with a Rockwell of C-62 to 64 will often cut easily, when using a standard 10-in. mill bastard file.

Comparisons of cutting hardness are dependent upon three factors: (1) The size, shape, and hardness of the files; (2) the speed of moving the file across the hardened part; and (3) the pressure and angle of the file while moving. The first item can be standardized by using nothing but files especially made for testing or 10-in. mill bastard files made by a reliable manufacturer. The second and third items are acquired by the skill of the workman. The slower the speed the more accurate is the test, because high speeds will wear off the surface of both the part and the file, thereby giving a false indication of softness.

Hardness testing by means of a file has a limited range of application because any material cut with the file cannot be appraised. It is merely classed as "file soft." Thus its usefulness must be confined to a certain high hardness value, with a minimum of approximately Rockwell C-58 to C-60, dependent upon the steel and its treatment. Its utility on drawn parts might be limited to a still higher hardness range.

Cost of the test is dependent less upon labor costs than upon the life of the files used. When testing parts having narrow contacts with the files the teeth are worn and broken quickly (thereby allowing only a few strokes to each area on the file), but skilled workmen will be able to use the full width of the file in this manner. For wide specimens the teeth wear more slowly but uniformly, necessitating care to discard the file when it is too dull for good use.

In conclusion, the rapidity of the file test keeps it as a regular means of testing hardness and decarburization, but it is limited to a small range of usefulness — mostly on hardened parts, not drawn.

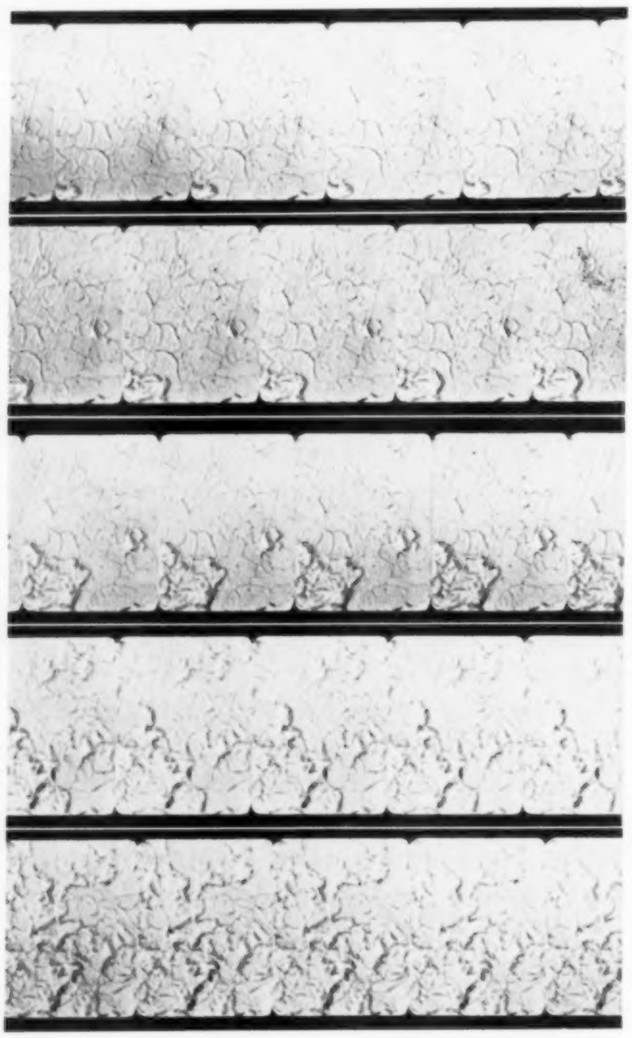
H. T. MORTON

CORRESPONDENCE AND FOREIGN LETTERS

Movie of Metals at High Heat

CAMBRIDGE, *Mass.* — So many questions have been asked concerning the equipment that was used to obtain the motion picture, "Surface Changes in Metals at High Temperatures," shown before many chapters of the American Society for Steel Treating that the following brief note may be in order.

The method was essentially that used in all photomicrographic work but involved three modifications. First, the sample was placed in a closed container within the heating element of a miniature electric furnace mounted on a microscope stage, and was watched through a fused silica window. Second, a motion picture camera from which the lens had been removed was substituted for the usual camera box. Third, a prism arrangement that permitted simultaneous visual observation of the area being photographed was placed between the microscope and the camera.



A_3 Transformation Sweeping Over Pure Iron

In the photograph the furnace lid has been removed and is to be seen lying on the table top. Water connections for cooling the outer shell and cover, and also the tube that introduces hydrogen into the furnace for the prevention of oxidation, have been removed.

The magnification on the film was about 30 diameters. The camera was driven at about its normal speed for ordinary motion pictures. The accompanying sections of film are contact prints from the original negative and show the A_3 transformation in the process of sweeping over a piece of Armco ingot iron which had previously been annealed at a high temperature. Other portions of the film also show the melting of pure silver and of cadmium-bismuth and copper-nickel alloys.

BRUCE A. ROGERS
LELAND R. VAN WERT

Martensite Forms Instantly

CHARLOTTENBURG, *Germany* — About a year ago, the writer, at the instigation of Professor Hanemann, director of the Metallurgical Institute at the Technischen Hochschule, Berlin, succeeded in watching the crystallization of martensite directly in the microscope and in photographing the transformation on a motion picture film. The latter has been shown a number of times to engineering groups and received enthusiastically.

If a steel with 1.7% carbon is quenched in a metal bath at 100° C., the crystallization of pearlite will be completely suppressed; the undercooled austenite is extremely stable if held at this temperature, and can be ground, pol-

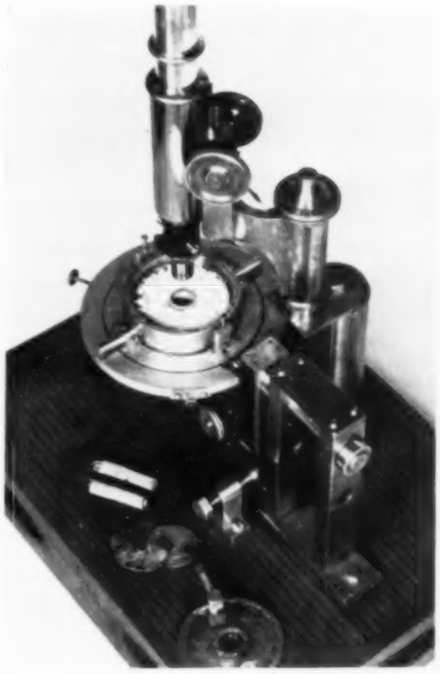
ished, and etched. Homogeneous austenite is thus obtained for observation. All that is necessary is to keep the specimen hot, which can easily be done by forcing it into a drilled hole in a soldering iron, electrically heated.

If the steel is then allowed to cool, martensite crystallizes out from the austenite grains. Since the change involves an increase in volume, the martensite needles appear in relief, and can be observed and photographed.

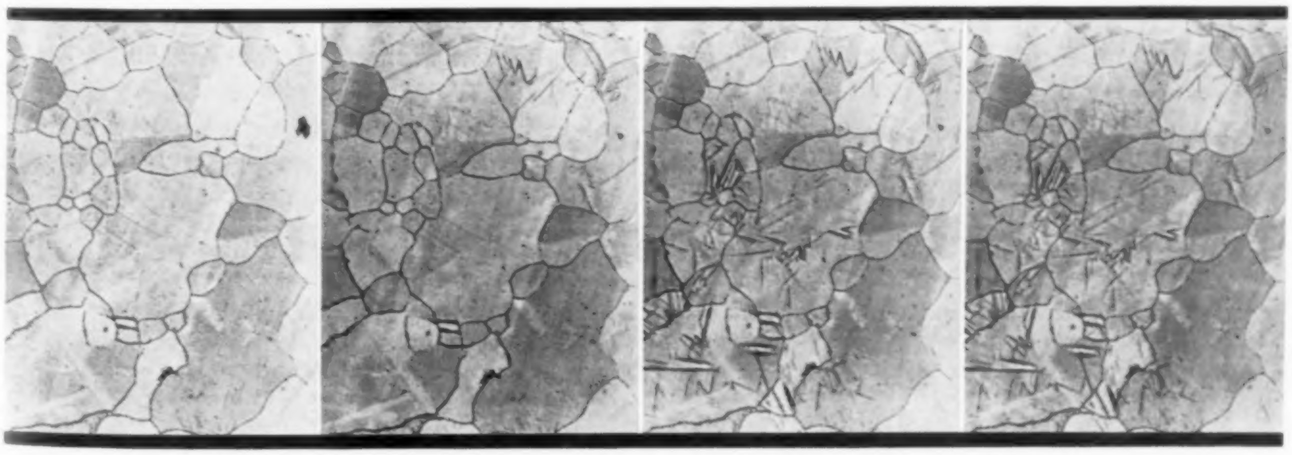
Four consecutive exposures, 1/20th of a second apart, are reproduced on this page. Even with slow and uniform cooling the martensite needles appear suddenly full size and grow no larger. The precipitation takes place by fits and starts; that is, needles form at random places, usually appearing simultaneously in several crystals.

This peculiar birth of martensite is in keeping with what we know about the space lattice of the atoms. According to E. C. Bain's theory advanced in *Transactions, A.S.S.T.*, 1926, p. 752, the tetragonal lattice of martensite may be considered to be already contained in the lattice of austenite. For transformation of austenite into martensite it is only necessary that the spacing between atoms on one crystallographic axis be shortened, and lengthened on the two others. The change is the result of two opposing tendencies, first, the immobility of the cold carbon which obstructs atomic rearrangement, and, second, the tendency of the iron atoms of the undercooled austenite to expand into the alpha space lattice.

At a certain temperature range the influence toward expansion overpowers the obstruction offered by carbon and the transformation of austenite to martensite then occurs. Some additional energy is necessary (that is, an additional undercooling) in order to pry the iron atoms away from the carbon atom; when this happens large blocks of the lattice suddenly col-



Electric Furnace (Cover Aside) to Heat Samples Under Microscope

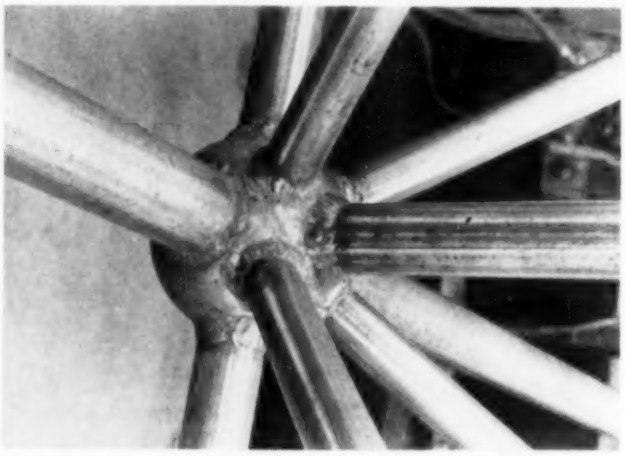


Four Successive Exposures at 20 Per Sec. Enlarged about 2½ times

lapse. This explains the peculiar jerky nature of the crystallization.

By applying this new method of research to other metals and alloys, we hope to widen substantially our knowledge of the phenomena of transformation in the solid state.

H. J. WIESTER



Tubes Welded to Spheres

STOCKTON ON TEES, *England* — Welding has become such a useful tool to the chemical industries, and pipe is so omnipresent in the plant, that we in the Imperial Chemical Industries have made special studies looking toward the utilization of welded pipe for all sorts of structures. While I-beams and channels are better structural shapes for beams to resist bending, round members which have to bear compression or tension are theoretically much better than angles, tees, or even rectangular bars.

One difficulty has not previously been surmounted; namely, the joint at tubular intersections. In conjunction with Harold Kenney and R. A. Smith, my assistants in the welding department, we have worked out and patented a spherical joint, illustrated at the head of this letter, which we believe eliminates the former difficulties. A full account of its development and applications has been submitted in a paper to the second Lincoln Arc Welding Prize Competition.

It cannot be denied that the symmetry of a circular shape appeals to the eye. Imagine what a bicycle frame would look like if it were composed of the usual structural members! This very bicycle frame illustrates one of the possible methods of joining tubes, namely special sockets brazed or screwed into or over the tube ends. For structures, this plan is objectionable because it adds considerably to the weight, requires a large stock of connectors, and is costly.

A Dutch engineer has proposed that the tube-ends should be pressed into the shape of angle or tee sections, and the latter may then be bolted or welded together. Fittings of the same design could also be used. Again, this idea requires costly and heavy machinery, or a large stock of fittings.

The standard method, used widely for aircraft fuselages and undercarriages, is to weld the tubes directly to one another after having previously shaped the ends to fit. This cutting and fitting is exceedingly costly; futhermore the welding is difficult in acute angles and liable to overheat the metal where a number of tubes intersect. Sometimes stresses brought in by diagonals are beyond the crushing strength of the tubes, so an axial plate may be inserted in slots (the so-called plate insert joint). We have found this expensive as to slotting and welding up exposed tube-ends.

Our scheme to overcome these difficulties is to unite intersecting tubular members on the surface of an inserted sphere. The view at the outset shows a complicated cluster, and explains the system more adequately than words. Each member is joined at right angles to its axis, the line of contact being a circle. All tubes may therefore be cut off square, which is the cheapest possible operation. When such a tube touches the sphere at all points, its axis passes through the center of the sphere; any sideways eccentricity is avoided almost automatically, and assembly is correspondingly expedited.

Our spheres have been made by pressing

hemispheres from flat plate, trimming the edges, and welding two together in an ordinary resistance machine using hemispherical copper chucks. A series of tests shows that if spheres are $1\frac{1}{2}$ times the diameter of the largest tube at the joint and have a thickness $1\frac{1}{2}$ times the thickness of the heaviest-walled tube, the joint will be stronger than the tubes themselves.

We attach a summary of results for shop, erection, and painting costs of an overhead steel pipe trestle, 126 ft. long in four spans, recently erected in our plant. It is designed to carry a load of 336 lb. per ft. run. The higher cost per pound of the tubes is more than offset by the economy in weight and painting (line 3).

We are convinced by much detailed study and tests that there is ample justification for increasing the working stress up to the yield point of the material when all loads are known and fully allowed for, owing to the complete absence of eccentricity at the joints and in the members. Line 4 shows what important savings can then be made.

A. F. Burstall

Oil Immersion Objectives

New York — To my greatest consternation, I have found that upon printing my paper in the January issue of Metal Progress a mistake had occurred which changes the contents of one of my statements so completely that I think a correction is necessary.

In the first paragraph on page 20, it appears as if I believe that oil immersion objectives are of no value for metallurgical work. I had never intended to make a statement of this kind. I had reference to immersion objectives using liquids of a *higher* refractive index than oil (as for instance monobrome-napththalene immersions). About the superiority of oil immersions over dry systems there can never be any doubt, but these immersion objectives for liquids of higher indices have not been very successful.

I would greatly appreciate it if these corrections could be brought to the attention of the readers in the next issue.

With further reference to the Table of Contents, on page 1 of Metal Progress, I wish to mention that my given name is Wolfgang and not Werner, as printed. This correction may likewise be brought to the attention of the readers, inasmuch as Dr. Werner Zieler has in the past also been a contributor.

W. Zieler

Instantaneous Refining Reactions in Slag-Steel Emulsion

Paris, *France* — The essential characteristics which distinguish quality steels from ordinary steels are their uniformity, chemical purity, and a minimum content of non-metallics. These inclusions come from the deoxidizers added to the metal before tapping; this operation (which is wrongly called deoxidation) really consists of converting the oxides dissolved in the liquid steel into some other oxidized non-soluble components (such as oxides, silicates, or aluminates).

Actual deoxidation — that is to say, the elimination of oxygen from the metal — occurs

COMPARATIVE COSTS OF 126-ft. PIPE TRESTLE

	Working Stress Lb. per Sq. In.	Weight of Structure	Painted Surface Sq. Ft.	Cost			
				Material	Labor	Overhead 100%	Total
Conventional riveted design	18,000	8,007 lb.	1,286	\$156.30	\$148.60	\$148.60	\$453.40
Conventional welded design	18,000	7,360	1,246	152.20	135.00	135.00	422.10
New type construction with tubes and spheres	18,000	4,296	630	192.30	87.70	87.70	367.70
Same, no allowance for eccentricity	31,400	3,247	615	141.60	84.60	84.60	310.70

only when the oxidized inclusions have been removed. It may occur by flotation, but this is never completed because the finest particles remain in suspension almost indefinitely. True deoxidation of quality steels, without the formation of inclusions, is done when the dissolved oxide in the melted metal is absorbed in an appropriate acid slag which "washes the metal." In the same way, dephosphorization and desulphurization may be done with basic slags able to absorb phosphorus and sulphur.

There appears to be a certain antagonism between the relatively slow and expensive methods used to obtain high grade steels, and the cheap and rapid manufacture of ordinary steels. There has also been a contrast between the irregularity of "hand-made heats" and the almost automatic operations needed for mass production.

We may say that metallurgists have always been preoccupied by three ambitions: 1. To insure perfect regularity of manufacture; 2. To reduce the impurities (chiefly by deoxidation); 3. To speed up operations, so as to decrease the cost and save the refractories.

Each one of these objectives has been met singly, but not the three simultaneously. Thus, physico-chemical laws indicate that one heat will duplicate another when equilibrium is reached between the metal-slag system, since the partition of elements is quite definite for every temperature. Furthermore, deoxidation and purification of the melted metal may be pushed to the limit with a proper slag.

However chemical friction (or passive resistance) impedes physico-chemical equilibrium. What is more to the point, it slows down the refining reactions between metal and slag. Passive resistance is accountable for the variation in time required to finish the heat, and in fact the extra time necessary for making first-class steel, and consequently, for the price of the operations.

In order to lessen this chemical friction and to increase the speed of reaction between the molten metal and slag, we must increase their fluidity, and the area of contacting surfaces across which the elements transfer from metal to slag and vice versa. Intimate contact of relatively small masses will avoid that slow diffusion in the very heart of the bath of steel and its covering slag which characterizes open-hearth practice.

Such accelerated operations have recently been achieved by a new process by R. Perrin. In some experiments at Aciéries Electriques d'Ugine Mr. Perrin noticed that when a very fluid slag of appropriate composition was melted in a separate pot, and then vigorously rabbled into the liquid metal, so as to produce an emulsion of the two, the desired reactions are extremely rapid — almost instantaneous.

Several experiments on the dephosphorization of steel by basic slags gave reproducible results. When puddling was violent enough, one minute was sufficient to reduce the phosphorus content of 15 tons of metal from 0.45 to 0.045% or from 0.06 to 0.01%.

Steel was also rapidly deoxidized with acid slags having a high solvent power toward iron oxide. The usual acid slags are viscous at furnace temperatures, and the reactions are consequently slow. One must therefore synthesize more fluid slags of good electrical conductivity. Such slags attack the linings very rapidly, but since the oxides are dissolved from the metal after a very short and intense mixing, the damage to the furnace walls is minimized. This fact differentiates very clearly this new kind of metallurgy from the conventional acid practice.

Very fluid acid slags (more fluid than the oxidized basic slags) are necessary, carburetted before mixing with the metal. Some materials are also added to the steel (before puddling) whose oxides are less soluble than iron oxide. Intense puddling of the super-oxidized bath with this special slag produced properly killed steel without the addition of ferrosilicon or aluminum. The cycle is completed by regenerating the slag by puddling it with metal deoxidized by silicon or aluminum.

A. Portevin

Miracle Worker, AGE 8

His little hands hold the instrument tightly; his small, confident voice speaks eagerly into the mouthpiece. And as simply as that, he talks to his friend who lives around the corner, or to his Granny in a distant city . . . achievements which, not so many years ago, would have seemed miraculous.

These miracles he takes as a matter of course, in the stride of his carefree days. You yourself probably accept the telephone just as casually. Seldom do you realize what extraordinary powers it gives you. You use it daily for a dozen different purposes. For friendly chats. For business calls. To save steps, time and trouble. To be many places, do many things, visit many people, without so much as moving from the living room of your home or the desk in your office.

At this very moment, somewhere, your voice would be the most welcome music in the world. Some one would find happiness in knowing where you are and how you are. Some one would say gratefully, sincerely—"I was wishing you'd call."

From among more than seventeen million telephones in this country, the very one you want will be connected quickly and efficiently with the telephone in your home or office.

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CONCENTRATES

from the current technical press

SPECIALIZATION is become so intense that general works on metallurgy are almost useless; textbooks on iron and steel are for beginning students; even treatises on alloy steels are too sketchy to answer many specific questions. The future will produce volumes on individual alloying metals, and sizable books on the utility of a single important composition. It is to be hoped that they will measure up to the standard of excellence set by the first monograph of the Alloys of Iron Research — **ALLOYS OF IRON AND MOLYBDENUM** by J. L. Gregg. (Published for Engineering Foundation by McGraw-Hill Book Co., New York, at $6.00.)

From early announcements of the Engineering Foundation, many acquired the idea that the survey of literature — of which this book forms a part — was to be confined to alloys of "pure" metals. This, of course, is but a small part of the story, and in the Fe-Mo system represents principally the work of Sykes in America and Takai in Japan. Nearly all of Mr. Gregg's work consisted of collecting, appraising, and collating the available information on the commercial steels and irons containing useful quantities of molybdenum. He reprints a great amount of numerical data, so that any reader who is inclined to doubt the summary may draw his own conclusions. In numbers of places, conflicting evidence has been submitted to a recognized expert and his appraisal has been given. Important chapters devote themselves to such up-to-the-minute subjects as molybdenum cast irons, molybdenum high speed tools, and molybdenum nitriding steels.

Not the least of the excellences of this volume is the draftsmanship exhibited in the 150-odd diagrams.

A SECOND example of the specialized monograph is "Plastic Working of Metals and Power-Press Operations" by E. V. Crane (published by John Wiley & Sons, New York, at $4.00). The author rightly assumes that for every person interested in the details of the press construction, there will be a thousand who want to know the various things that can be done with **POWER PRESSES.** Faced with the situation that die design is still an art, and its application a matter of individual skill, he states that the success or failure of a given operation always leads back eventually to the inner structure and change in structure of the metal being worked, and takes what little is known (scientifically) of the plastic flow of metal and boldly attempts to correlate it with the art of die design.

Since the variations in die design are infinite, the most Mr. Crane can do is to subdivide the possible operations into shearing, forming, drawing, and coining, and sketch the fundamental forms of the various mechanisms which have been devised. Thus his book becomes a store of ideas for the engineer or technician who is continually faced with the problem — "Can I make this part with the available tools and available metal, and if not, what changes are necessary?" While the most of the book applies to work on sheet metal, extrusion, ironing, coining and cold forging (to very close tolerances) get their share of attention.

AN INTRODUCTION TO METALLOGRAPHY has been issued by L. W. Eastwood, instructor at College of Mining and Technology, Houghton, Mich. It follows the classical plan

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whereby the student early tackles the phase rule (more difficult to understand and use than the third law of thermodynamics) and is then shown about a score of type diagrams before making his bow to the iron-carbon system, the most important and just about the simplest of all. While the present text has useful chapters on the technique of polishing and microscopy, it would appear that the matter on equilibrium diagrams is more suitable to an advanced course than to an "Introduction." One hates to speculate on how many prospective metallurgists have been scared away by that abstraction of abstractions $F = C - P + 2$.

ZIRCON (the silicate) is prepared for refractories as a fine sand. Since a coarser-grained material is necessary for **ZIRCON BRICK**, the sand is fused into "grog" by an electric arc and crushed. In the course of a 5-year research program on zircon and zirconia (reported by G. F. Comstock in *Journal*, American Ceramic Society for January), it was found that grog which is sintered instead of electrically fused gives a brick less liable to cracking in manufacture and deterioration in service. The brick is made of 50% grog, 30% refined zircon sand, and 20% refined milled zircon fired to 1600° C. in an oil furnace. Recommended binders are dextrin and boric acid, or caustic soda, although goulac and lignin work better in large hand-rammed shapes. Zircon has a satisfactory resistance to bessemer and acid open-hearth slags, but shows a tendency to combine with basic slag. Zircon nozzles erode and melt less than clay, thus avoiding scabby ingots and slag inclusions in steel. Semi-permanent foundry molds were not promising enough to warrant competition with sand molds. Zircon bonding increases spalling resistance of magnesite brick and cement but does not improve other refractories. Zircon crucibles are superior to graphite for such purposes as melting platinum but there is danger of silicon contamination. Zirconia (the oxide) was therefore used and found to be more refractory and slag resistant though more expensive.

NEW equipment for making small bars, shapes, and hoops at Carnegie Steel Co.'s McDonald (Ohio) plant is described by T. H. Gerken, *The Iron Age*, Oct. 27, 1932. Twelve **BAR MILLS** are built, side by side, with billet yards and heating furnaces across one end, and large warehouses along the other. Material other than steel in process is brought into the mills through a large subway running at right angles to the center lines of the mill buildings. All mills are continuous and high speed. The latest have vertical rolls with overhead motors on the finishing stands. This avoids twisting the hot metal at high speed. The 800-hp. motors are mounted on heavy C-shaped frames, the open part of the C permitting rolls to be readily changed. This entire housing may be moved sideways so the roll opening matches the passes in horizontal rolls on either side, whereupon it is clamped to its foundation by hydraulic jacks. The vertical rolls are splined on the end and slip into an appropriate sleeve on the lower part of the motor shaft; thus vertical adjustment may be made by means of counterbalanced lower bearings. Coiling and conveying mechanisms are highly developed and controlled by unique electrical equipment actuated by photo-electric cells.

MANY applications of medium manganese steels (say 0.20 C, 1.5 Mn) for cheap parts intermediate in strength between plain steel and the chromium-nickel steels are handicapped by the fact that such steels must be quenched from the tempering heat, else the impact strength is quite low. W. F. Rowden in *Metallurgia*, November last, notes that the addition of 0.2 to 0.4% molybdenum to **MEDIUM MANGANESE STEELS** will cure this defect almost completely, and also induce the property of deep hardening. He quotes figures for an analysis on the low side which shows almost constant physical properties of sections from 3/4 to 1 1/2 in. diameter, oil hardened and tempered at 1200° F. Similar samples normalized at 1550° F. and tempered at 1100° F. were slightly softer but still quite

CONCENTRATES

uniform except that Izod impact on the small samples registered 115 ft-lb., and on the large bars 70 ft-lb.

NICKEL-chromium resistance alloys can withstand temperatures of 1050 to 1150° C.; a non-metallic alloy of silicon and carbon can be used up to 1500° C. but is brittle and limited in design. **KANTHAL**, a new resistance alloy of aluminum, chromium and cobalt, described by J. H. Russell in *Metallurgia*, October, 1932, combines the advantages of temperature resistance and flexibility of available forms. Its specific resistance is higher and its specific gravity lower than Ni-Cr alloys; scaling temperature is above 1350° C. Kanthal is produced as strip, wire, or castings in three grades for use at 1325, 1250, and 1050° C. respectively (2400, 2300 and 1900° F.). It is used for heating elements in furnaces for hardening high speed steel, heat treating stainless, case hardening, sintering tungsten carbide, glass melting, enameling, and pottery, and for pyrometer sheaths and hearth-plates. At air temperature the alloys are brittle, especially in heavy sections, and large sizes of wire and strip should be heated when coiled or bent.

AN American installation of a rotary melting furnace using pulverized coal (a popular development in Europe, discussed by F. Giolitti in METAL PROGRESS correspondence columns last spring) is described by D. J. Reese in American Foundrymen's Association *Transactions* for December, 1932. This 2-ton **BRACKELSBERG FURNACE** has been used for melting both malleable and high test gray iron, 407 heats having been tapped since its installation in November, 1930. The burner uses air from two sources — primary to convey the pulverized fuel to the burner, and secondary air for combustion. The flame reaches a temperature of 3000° F. — 3150° if the secondary air is preheated to 600° F. An analysis of nine heats, *(Cont. on page 58)*

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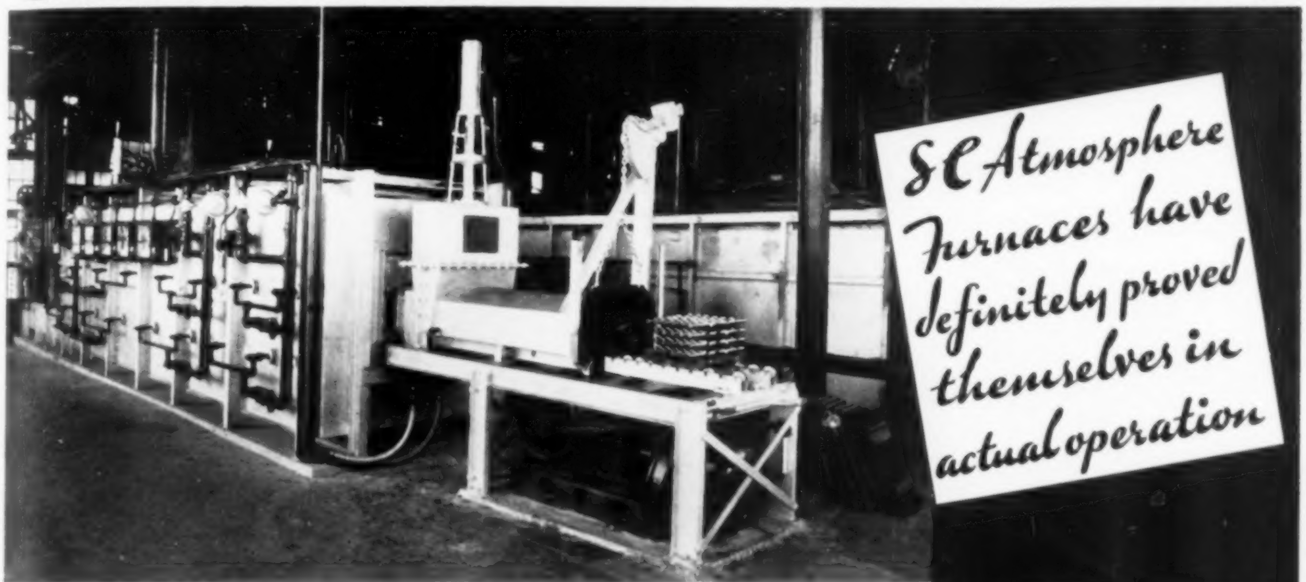
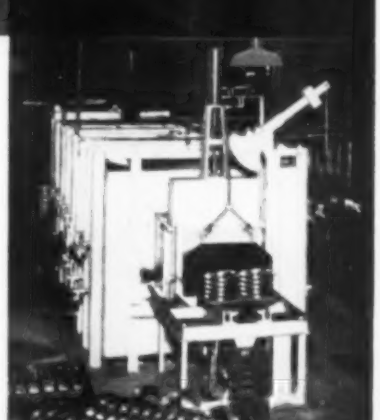


1. Elimination of cost of carburizing boxes
2. Elimination of cost of carburizing compound
3. Reduction of 60% in floor space
4. Reduction of 50% in labor cost
5. Reduction of 35% to 60% in total operating cost



These important savings have been proved on automotive parts in the plant of a large manufacturer, after fourteen months of operation (with no expense for furnace maintenance).

With these savings came better control of the type and character of the case. There were other important advantages that will interest you.

Your carburizing can have these added savings . . . this better control—both of them definite and applicable to all production jobs. If you are interested in the application of continuous gas carburizing to your processes, now or in the future, write us. We'll be glad to tell you all about the adaptation to your carburizing methods.

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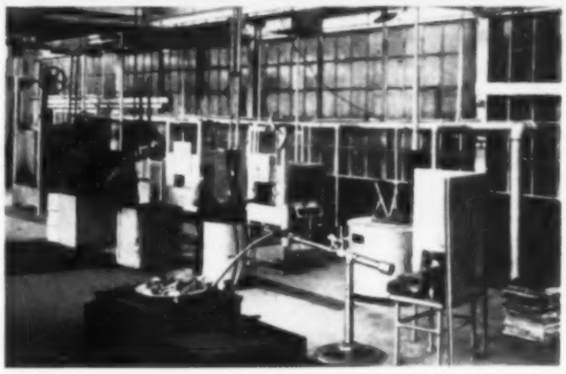
The Heat-Treat plant using the batch type method must be modern in every respect to obtain uniformity of quality and to meet strict specifications in line with today's demands.

SC Standard Furnaces are the results of years of continuous research and experience in design and manufacture. These furnaces meet today's demands of metallurgical and production specifications.

At the right is a typical installation of SC Furnaces for batch operation.



ASK FOR THESE USEFUL PAMPHLETS

Alloys of Aluminum

Data and tables describing the physical properties and chemical constituents of the several alloys of aluminum are presented in a carefully prepared booklet issued by Aluminum Co. of America. An authoritative discussion of these alloys. Bulletin Fe-54.

Phosphor Bronze

American Brass Co. has issued a beautiful pamphlet which describes the commercial forms of Anaconda Phosphor Bronzes, a series of deoxidized copper alloys containing up to 10% tin, notable for high tensile strength and resistance to fatigue, corrosion and wear. Bulletin Fe-89.

Furnaces and Burners

Photographs and descriptions of practically every type of heating furnaces are contained in a folder recently put out by Surface Combustion Corp. to describe its scope of activities as manufacturers of standard and special furnaces and burners. Bulletin Fe-51.

Heat Treating Data

Brief but accurate summaries of the proper treatments for annealing sheets, wire, welded tanks, malleable castings and forgings are given in a book published by Brown Instrument Co. Normalizing, tempering, hardening and carburizing recommendations as well as many special treatments are included. Bulletin Fe-3.

Stabilog

Continuous rather than batch processes are controlled at all times by Foxboro Co.'s new Stabilog, in which a differential pressure motor moves the throttling range of the master valve in anticipation of variations in the rate of change at the controlled point. A booklet thoroughly describes it. Bulletin Fe-21.

Micro-Metallograph

Metallurgists will be interested in the description of the Leitz Model MM-2 Micro-Metallograph. This simplified instrument at low cost provides all essential optical and mechanical equipment to meet the requirements of industry. Bulletin Fe-47.

Turbo Compressors

A series of three bulletins is available from Spencer Turbine Co. describing their Turbo Compressors for oil and gas fired equipment and foundry cupolas. Sizes range from 100 to 2,000 cu. ft., 1 to 300 h. p., 8 oz. to 5 lbs. Bulletin Fe-70.

Furnace Parts

Various parts for furnaces made from alloys manufactured by Driver-Harris Co. are pictured and described in an interesting publication. Complete performance data and specifications of Nichrome and Chromax heat resisting alloys are given in the booklet. Bulletin N-19.

To Prevent Rust

The well known rust preventive, No-Ox-Id, is now available from Dearborn Chemical Co. as a foundation for paint. It is available in the colors red, gray or black. A booklet explains how maximum resistance to corrosion can be obtained. Bulletin Ju-36.

Welding Mn Steel

Metal and Thermit Corp. offers a new bulletin describing the Murex method of welding manganese steel which utilizes a heavily coated chromium-nickel rod for a strong, ductile joining material and overlays it with wear-resisting manganese steel containing a little nickel. Bulletin Fe-64.

How to Test Wear

Tests of lubricants or of wear of moving parts may be made accurately with a new machine, made by Timken Roller Bearing Co. A bulletin tells how the machine tests the load carrying capacity of lubricants and measures the friction and wear of materials. Bulletin M-71.

Welded Pipe

The process used by Republic Steel Corp. in manufacturing electrically welded pipe and casing is described in a well illustrated booklet. A presentation of data on performance of the pipe under both laboratory and field tests is interesting. Bulletin A-8.

Allegheny 46

This alloy has strength at high temperature and couples corrosion resistance with ease of fabrication. Allegheny Steel Co. has issued a bulletin covering the chemical and physical properties of this low alloy heat and corrosion resisting steel which has many applications in furnace equipment. Bulletin Fe-92.

Scleroscopes

The model D standard recording scleroscope is described and illustrated in a recent publication of Shore Instrument Co. The theory and practice of hardness testing with this portable machine as described in this bulletin reveal a fund of valuable facts. Bulletin S-33.

Q-Alloys

Authoritative information on alloy castings, especially the chromium-nickel and straight chromium alloys manufactured by General Alloys Co. to resist corrosion and high temperatures, is contained in one of that company's publications. Bulletin D-17.

Cyanides and Salts

Metallurgists will find valuable information in an 80-page booklet published by R & H Chemical Department of E. I. du Pont de Nemours Co. Technical information on the heat treatment of steels with cyanides and salts is presented in a lucid manner. Bulletin D-29.

Recuperators

The complete story of recuperators built by Carborundum Co. for industrial furnaces is told in a readable booklet. The range of types available is described and the operating conditions are outlined in a clear manner. Bulletin F-57.

Annealing Forgings

Not only annealing furnaces are described in a recent publication of Electric Furnace Co. Various types of electric and fuel fired furnaces designed for heat treating forgings are described and clearly illustrated. Bulletin Fe-30.

Refractories

A semi-technical booklet prepared by Norton Co. gives valuable information on the manufacturing processes and the various industrial applications of fused alumina (Alundum), silicon carbide (Crystolon) and fused magnesia refractories products. Bulletin J-88.

Globar Elements

Globar electrical heating units and a variety of accessories for their operation have been catalogued by Globar Corp. A list of the standard industrial type heating elements and a coordinated list of terminal mountings and accessories is included. Bulletin N-25.

Liquid Baths

A competent discussion of liquid baths for heat treating steel at temperatures from 350 to 1800° F. appears in a recent publication of E. F. Houghton & Co. A valuable chapter is devoted to the proper design of furnaces for use with liquid baths which lists 20 general furnace requirements. Bulletin Ja-38.

Titanium in Steel

An elaborate catalogue prepared for technical readers describes the use of ferro-carbon titanium in steel. Titanium Alloy Manufacturing Co. prepared it. The application of titanium in steels for forgings, castings, rails, sheets and plates is thoroughly described. Bulletin J-90.

Homo Tempering

The use of the Homo furnace in tempering is described in detail in a booklet prepared by Leeds & Northrup Co. Photographs and data show the range of sizes in the line of Homo furnaces. Emphasis is laid on the advantages of the Homo method of tempering. Bulletin D-46.

300 Stainless Uses

Stainless steels are undoubtedly the most widely used of the alloy steels, according to the very interesting booklet on this subject just issued by Electro Metallurgical Co. Over 300 industrial uses of chromium and chromium-nickel steels are described in considerable detail. Attractively illustrated. Bulletin Ja-16.

Super Blowpipes

The advent of natural gas has made the replacement of many burners imperative. American Gas Furnace Co. describes in an illustrated folder blowpipes, ribbon burners, cross-fires, hand torches, etc., which are suitable for use with natural gas, propane and butane. Bulletin Ja-11.

New Microscope

A new low power binocular microscope is offered to metal men by Carl Zeiss, Inc. A booklet to describe it has been prepared. The new microscope is valuable in examining fractures, surfaces, etc., at magnifications from 4 to 31 diameters. Bulletin MIK-464e.

Heating Units

An unique and very useful device for calculating heating units when figuring coiled units, covering wattages from 275 to 1000, has been prepared by Hoskins Mfg. Co. Two slotted cards are clamped back to back through which various data can be read by adjusting a card which slides between. Bulletin D-24.

Big-End-Up

Gathmann Engineering Co. briefly explains the advantages of steel cast in big-end-up ingots, showing the freedom from pipe, excessive segregation and axial porosity. An 82% ingot-to-bloom yield of sound steel is the usual practice. Bulletin Fe-13.

Atmosphere Control

Furnaces equipped with "Atmosphere Control" as manufactured by Hevi Duty Electric Co. are described in a new bulletin. Operation of the atmosphere control device is described and specifications are presented. Bulletin Ja-44.

METAL PROGRESS,
7016 Euclid Ave., Cleveland.

Please have sent to me the following literature as described under "Helpful Literature" in the February issue. (Please order by number.)

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CONCENTRATES

(Continued from page 54) containing 12 or 13% steel in the charge, shows the uniformity of chemical composition and physical properties obtainable with the rotary furnace. In another experiment a 3000-lb. heat analyzed 2.76% Si and 2.64% total carbon. After tapping 1000 lb., adding 200 lb. steel and ferrosilicon, and holding ½ hr., it showed 2.85% Si and 2.41% C. After tapping a second 1000 lb., adding 100 lb. steel, and holding ½ hr., it contained 2.66% Si and 2.21% C. Sulphur, phosphorus, and manganese varied only slightly.

TIN PLATE which is used for deep drawing must possess a fine grain structure. E. S. Lawrence, in *Heat Treating and Forging*, November, 1932, notes the effect which the two conventional methods of producing this material have upon grain size — the old, which utilizes two-high mills for rolling followed by normalizing in a continuous furnace, and the new which rolls the strip on continuous four-high mills followed by annealing. The latter produces small grain size without NORMALIZING, because the extreme reduction of the four-high mill strains the structure to such a point that critical grain growth and rearrangement of crystalline structure will take place at the subsequent low-temperature anneal. Since deep drawing plate takes only 5 to 10% of the total tin plate tonnage, the installation of continuous normalizers in the old method is proportionately costly, but this problem may be solved by substituting an open or black anneal in the normalizer for the customary box anneal before pickling and coating.

CADMIUM plates are usually brightened by dipping in dilute nitric acid, which dissolves some of the metal. Unfortunately, the acid also appears to form ammonium salts with traces of the electrolyte, and as these are not entirely removed by subsequent washing, they are the source of later *(Continued on p. 62)*

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(Continued from p. 58) discoloration or tarnish. According to Gustaf Soderberg (*Metal Cleaning & Finishing* for October), this may be avoided by proper ventilation of the stored pieces. He has also developed and patented a new solution for **BRIGHT DIPPING**, which is free from the bad effects noted above for nitric acid. It consists of a solution of chromic acid containing sulphuric acid radical, wherein the ratio (expressed in grams per liter) of CrO_3 to SO_4 is slightly over 20. Immersion of 50 sec. is recommended. The brightening action reduces the chromic acid, and it must be replaced or reoxidized at appropriate intervals.

BIMETALS made of mild steel clad on one side with corrosion resisting metal, like pure nickel or the high chromium-nickel steels, have recently been marketed for equipment which does not justify the solid expensive metal. Fabrication, especially **WELDING OF BIMETAL** into tankage, has been described by J. G. Schoener and F. G. Flocke in *Journal*, American Welding Society, last November, and S. L. Ingersoll in *Welding Engineer*, last October. Butted sheets, 10 gage and lighter, are best welded through from the protected side, using a coated electrode or fluxed welding rod designed to deposit metal of correct chemical composition. Thicker sheets are best beveled; if the coated side is open, the first thin layer should be made with soft steel. After careful cleaning, the rest of the joint is filled with the special alloy rod. If the soft steel backing is open, the order is of course reversed. Similar methods may be pursued for plates, ¼ in. thick or greater. An alternative method is to weld a V notch, open from the back, with soft steel, then groove down the root of the notch on the stainless side with a suitable tool, and fill the channel with alloy rod. A succession of thin layers will prevent excessive iron pick-up by inter-diffusion. From 3 to 15% of iron will be alloyed by pure nickel during welding, but this appears to have little effect on the service life.